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FUNDAMENTALS OF SHIFTWORK SCHEDULING

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THIS TECHNICAL REPORT HAS BEEN REVIEWED AND IS APPROVED FOR PUBLICATION.

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This report is designed for use by managers, supervisors, shiftwork schedulers and employees. It defines the principles and components of a method of shiftwork scheduling for regular, cyclic shifts that can minimize fatigue effects in the workplace. The report scheduling approaches, assessment tools and examples. Subjects discussed include fatigue, safety, calendar arithmetic, circadian stability, the Principles of Chronohygiene, shiftworker satisfaction, the numbers of workers needed, the basic structure of shiftwork systems and plans (rotas), scheduling methods and examples for 1- through 5-crew solutions and complex solutions to the 24/7 work demand, assessments of schedule adequacy, and the effects of schedule changes.

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PREFACE

This Technical Report is one portion of the Air Force Research Laboratory's response to a recommendation made in the Air Force Inspection Agency's report of their Eagle Look, *Shift Worker Fatigue* (PN 04-602, May 2004): "Update and adapt the *Fundamentals of Shiftwork Scheduling Manual* into an AFMAN" (Recommendation Ob 1-1). This recommendation was endorsed by the Air Staff. The original Manual was written and copyrighted by the same author, Dr. Miller, in 1992 (Miller Ergonomics, Lakeside, CA) and is now updated and placed in the public domain in this Technical Report. The writing of this Report was supported by AFRL Job Order Number 7757P905. Several senior scientists with a great deal of applied research experience concerning night work, shiftwork, human cognitive performance, and fatigue effects reviewed this Report. Their significant contributions are gratefully acknowledged

SUMMARY

This report is designed for use by managers, supervisors, shiftwork schedulers and employees. It defines the principles and components of a method of shiftwork scheduling for regular, cyclic shifts that can minimize fatigue effects in the workplace. The report scheduling approaches, assessment tools and examples. Subjects discussed include fatigue, safety, calendar arithmetic, circadian stability, the Principles of Chronohygiene, shiftworker satisfaction, the numbers of workers needed, the basic structure of shiftwork systems and plans (*rotas*), scheduling methods and examples for 1- through 5-crew solutions and complex solutions to the 24/7 work demand, assessments of schedule adequacy, and the effects of schedule changes.

FUNDAMENTALS OF SHIFTWORK SCHEDULING

Chapter 1

INTRODUCTION

Section A--Background Information

Objectives. Shiftworker acquisition, retention and management are difficult problems for supervisors of 24/7 operations. Night work and shiftwork cause quality-of-life problems, *malaise* and fatigue for most people. The problems may take the form of inadequate interactions with the worker's family and with the worker's employer. They may also take the form of medical complaints, reduced productivity, high turnover, and high error rates. These responses are initiated by shiftwork-induced disruptions of normal daily and weekly social and physiological cycles. The disruptions diminish safety, productivity, and wellbeing. The basic cause of all of these problems is that humans are not properly designed for night work. Good shiftwork scheduling practices are needed to keep worker malaise and fatigue to a minimum during continuous operations. In 2004, good shiftwork scheduling practices appeared to be absent in most of the Air Force[1]. This Manual should help you design simple, optimal schedules for regularly-scheduled shifts that produce beneficial changes in the workplace. Specifically, you should (1) understand nine principles that should be applied to shiftwork scheduling; (2) understand the nine components of regularly-scheduled shifts, and learn how use the principles to specify the components; and (3) understand how to assess the effects of a change in regularly-scheduled shifts.

Users. The supervisor or manager who must create or revise one or more regular shiftwork schedules should use this manual. Personnel assigned to shiftwork may find the Manual useful for understanding shiftwork scheduling and for making constructive suggestions to supervisors for schedule changes.

Benefits. The fundamental benefit for the Air Force of improved shiftwork scheduling is derived from compliance with the directive given by Napoleon Bonaparte to his commanders: "*You must not needlessly fatigue the troops*"[2]. How does Napoleon's admonition apply to 24/7 work demands in today's weapons systems? Poor shiftwork schedules are "stupid" solutions to the 24/7 work demand. Because they induce needless fatigue, they cause the human components of a weapon system to become "stupid[3]." In

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[1] Air Force Inspection Agency (2004), *Shift Worker Fatigue*, Eagle Look PN 04-602. Also, JC Miller *et al.*, *Air Force Shift Worker Fatigue Survey*; Technical Report AFRL-HE-BR-TR-2005-0128, Air Force Research Laboratory, Brooks City-Base TX, August 2005.

[2] To the Armée d'Italie in 1796.

[3] *Stupid.* Slow to learn or understand. Tending to make poor decisions or careless mistakes. (American Heritage® Dictionary of the English Language, Fourth Edition, 2000, Houghton Mifflin Company)

turn, the operators become the weakest link in the system and the whole system may fail or produce erroneous results because of that weakness. A good shiftwork schedule is the most important factor in minimizing the prevalence of operator "stupidity" when we face a 24/7 work demand. Other factors include manipulations of the work environment and the use of pharmacological aids.

Shiftwork schedules often include day-to-day and week-to-week, last-minute scheduling. The structures of many shiftwork schedules violate principles drawn from experimental and industrial investigations of productivity, safety, health, and satisfaction. They also fail to account for the simple arithmetic of the calendar and its cycles. Changing from last-minute scheduling to Principle-based scheduling, or from a poorly-designed schedule to a Principle-based schedule, should produce some or even all of the following changes in your organization:

- Fewer on-the-job errors and increased productivity
- Increased morale and reduced turnover
- Reduced shiftworker medical compensation claims
- Schedule predictability
- Schedule equity across all shiftworkers
- Fewer consecutive nights of work
- Adequate off-duty rest periods
- Improved predictability of overtime costs
- Less management attention spent on individual workers' schedule changes

The last-minute scheduling of shiftworkers places a continuing strain on an administrator. The administrator is blamed by shiftworkers for perceived inequities in the schedule, and blamed by upper management for occasionally failing to provide enough shiftworkers.

Most shiftwork schedulers have received no formal schooling in shiftwork planning. There are few specialists in this area, and no standards exist. Most schedulers have graduated from the ranks of shiftworkers. They have an intuitive feel for the problems faced by shiftworkers, but often must inhibit those feelings to meet the demands of the around-the-clock work demand.

Overview of the Manual. Shiftwork researchers[4] have classified the common types of shiftwork as:

- Systems without night or weekend work (the "9-to-5" weekday job)
- Systems with night work but without weekend work
- Systems with both night and weekend work, or "continuous shiftwork." These systems are also called "24/7" systems.

Within the 24/7 domain, we may classify systems as:

- Regular, fixed
- Regular, rotating; for example, four crews and rotating 8-h shifts

[4] P Knauth, J Rutenfranz (1976), *International Archives of Occupational and Environmental Health*, v. 37, pp. 125-137.

- Irregular; varying numbers of crews and shift lengths; for example, the 5-day irregular work week of Federal Aviation Administration air traffic controllers[5], or the irregular schedules flown by air transport crews.

The only subjects addressed in this Manual are regular fixed and regular rotating schedules. However, a better understanding of regular schedules should improve your ability to schedule irregular shiftwork. Because of its complexity, irregular shiftwork scheduling requires resources beyond the scope of this Manual. A number of commercial enterprises provide software and technical support for this kind of scheduling. To find the available resources, search the World Wide Web with the keywords "shiftwork" (and "shift work") and "rostering."

The Manual is divided into seven chapters. In Chapter 1 you will find some background information, including the objectives of, the expected users of and the benefits of using the Manual. This section is followed by sections that present summaries of the fatigue and health and safety issues related to shiftwork (Sections B and C). The chapter ends with a brief discussion of how calendar arithmetic must be re-thought to prepare useful shiftwork schedules (Section D).

Chapter 2 provides descriptions of nine Principles that underlie good scheduling for regular shifts. The Principles describe the essential qualities that determine the intrinsic natures of regular shiftwork schedules. Chapter 3 provides discussions of nine components of regular shift schedules. The components generate the minimum number of decisions required to specify completely the composition of regular shiftwork schedules.

Chapter 4 leads you through the design process for regular schedules. It starts with the optimal solution: the use of four crews (Section B). Then it discusses 2-crew, 3-crew, 5-crew, 1-crew, and complex solutions to the demand for 24-hour-per-day, 7-day-per-week (24/7) operations. Chapter 5 describes methods for assessing the acceptability of regular shiftwork schedules. Chapter 6 presents some scheduling examples, and Chapter 7 provides some suggested additional reading.

[5] FAA ATCs slide the start and end times of shifts depending upon work demand. Controllers may leave work at varying times in half-hour increments from 2200h to midnight as air traffic declines at night, and others may start work at varying times from 0430h on in half-hour increments as air traffic builds in the morning. Some facilities actually shut down at night.

Section B—Shiftwork Fatigue

The Human in the Loop. In any human-machine system, including weapon systems, the most unpredictable component in the system is the human. After training and currency, the greatest contributor to that human variability is fatigue. Good human-machine system design exploits human strengths and protects the system from human weaknesses. This is a fundamental concept in human factors engineering. The human brings to a system much more powerful pattern recognition capabilities and decision-making skills than can be provided in software. However, the human also brings much more performance variability to a system than one finds in software and modern hardware.

Sources of Variability. Incomplete training and lack of currency are sources of human variability. When novices are learning to operate a complex system, they display a learning curve. Initially, their performance is quite poor and variable, but they learn the basics quickly. Next, their performance is noticeably better, on average, but still more variable than desired. Finally, as they approach the expert user level, their average performance is quite good and it varies only a small amount. Similarly, when an expert user becomes "rusty" in the operation of a complex system, their performance may be more variable than desired until they return to their expert level.

One of the primary hallmarks of human fatigue is performance variability. This is due to large amplitude, moment-to-moment fluctuations in attentiveness associated with fatigue. Average performance may be acceptable, but there are brief periods when responses are extraordinarily delayed or absent ("lapses"). We often call this "distractibility" and note that fatigued system operators are more easily distracted than non-fatigued operators.

Sources of Fatigue. Sleepiness and fatigue are different human states. You may recall times when you were fatigued but not sleepy. However, when we have asked workers for numeric ratings of sleepiness and fatigue across many days and nights of demanding work, their two sets of ratings have correlated very strongly. Thus, it appears that in our day-to-day activities we perceive the two states as changing in parallel most of the time. For the purposes of this Manual, you should view sleepiness and fatigue as being almost the same thing. We sort the generators of fatigue into the five categories: physical, circadian, acute, cumulative, and chronic.

Circadian Effects. There are normal, inherent, unavoidable, 24-hour rhythms in human cognitive and physical performance. Most of these circadian rhythms oscillate between a high point late in the day to a low point in the pre-dawn hours with a peak-to-trough amplitude of about 5 to 10% of their average value. Human circadian rhythms are slightly longer than one cycle per day, but are normally slaved, or entrained, to exactly one cycle per day by external time cues (*Zeitgebers*), especially the daylight-darkness cycle.

- **Jet Lag.** The feelings of malaise and fatigue that accompany a time zone change that is faster than about one time zone per day. Jet lag occurs during

the period of re-synchronization of circadian rhythms to new external time cues, especially the daylight-darkness cycle.

- **Shift Lag.** The feelings of malaise and fatigue that accompany a change from day work to night work and *vice versa*. Shift lag occurs during the period of attempted re-synchronization of circadian rhythms to new external time cues. Compared to jet lag, the attempt to re-synchronize to a night work and day sleep schedule occurs more slowly and is much less successful because the main time cue, the daylight-darkness cycle, tends to inhibit re-synchronization.

Acute Fatigue. Acute fatigue builds up normally and unavoidably within in one waking period, but recovery from acute fatigue occurs as the result of one good-quality, nocturnal sleep period.

Cumulative Fatigue. Cumulative fatigue builds up across major waking and duty periods when there is inadequate recovery (due to inadequate sleep) between the duty periods. Recovery from cumulative fatigue cannot be accomplished in one good-quality, nocturnal sleep period.

Chronic Fatigue. Chronic fatigue may set in after one to two weeks of cumulative fatigue. Its symptoms[6] are similar to those of Chronic Fatigue Syndrome (CFS). However, unlike CFS, the cause is known (continuing cumulative fatigue) and it occurs much sooner than the 6-month diagnostic requirement for CFS. The Air Force Safety Center has in the past called chronic fatigue "motivational exhaustion." While this label accounts for only one of several possible symptoms of chronic fatigue (apathy), it describes well the attitude that one observes in a person with chronic fatigue. It is possible that the long-term presence of chronic fatigue in an individual is one of the causes for the illnesses associated with chronic shiftwork (paragraph 8, below).

Nature of Fatigue. Fatigue is ubiquitous, pervasive and insidious. By ubiquitous we mean that fatigue affects everybody. There are individual differences: a few people are truly more resistant to fatigue effects than others. Many other people feel, without basis, that they are more resistant to fatigue effects than others. This misperception may cause them to form ill-advised intentions and/or to make bad decisions.

By pervasive, we mean that fatigue affects everything we do, physically and cognitively. Again, there are individual differences. In the physical domain, there are those who are inherently able to train to much greater levels of strength and endurance than the rest of us. This may also be true in the domains of cognition and attention: some people seem inherently less susceptible cognitively than most others.

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[6] The desire to sleep, apathy, substantial impairment in short-term memory or concentration; muscle pain; multi-joint pain without swelling or redness; headaches of a new type, pattern or severity; unrefreshing sleep; and post-exertional malaise lasting more than 24 hours.

By insidious, we mean that often when we are fatigued, we are quite unaware of how badly we are performing. Most people have experienced the attention lapse associated with mild fatigue when they miss a freeway exit or realize suddenly that they don't remember the last mile or two driven on the highway. Similarly, most people recovering from a period of physical, emotional or cognitive stress have uttered the phrase, "I didn't realize how tired I was!"

Understanding these aspects of fatigue, it is easy to see how we may become tricked into conducting safety-sensitive jobs[7] when we are too fatigued to be safe. If we think that we are more resistant to fatigue than we really are, and we don't realize that we are very fatigued, then we slog on toward the goal while making poorer decisions, accepting more risk and being more easily distracted than we should. This is not an intelligent approach to operations, though it has been the accepted approach on many occasions.

According to the National Sleep Foundation, lack of sleep is associated in the short term with irritability, impatience, anxiety, and depression. These problems can upset job and family relationships, spoil social activities, and cause unnecessary suffering. In the long term, shiftworkers may experience more stomach problems (especially heartburn and indigestion), menstrual irregularities, colds, flu, weight gain, and cardiovascular problems than day workers. It is not known whether shiftwork-related stressors or inherent characteristics of shiftworkers, related to their tendencies to self-select themselves for shiftwork, cause these chronic problems.

Quantitative Prediction of Fatigue. Fortunately, the biological changes and rhythms that cause fatigue-induced declines, lapses and variability in human performance are relatively lawful and predictable. There are quantitative models and simulations, implemented in software, that allow us to estimate and predict the timing and severity of fatigue episodes, given some information about when and how much people sleep. A world-class applied model (or simulation) was developed primarily with Department of Defense funding. The Sleep, Activity, Fatigue and Task Effectiveness (SAFTE) applied model integrates quantitative information about (1) circadian rhythms in metabolic rate, (2) cognitive performance recovery rates associated with sleep, and cognitive performance decay rates associated with wakefulness, and (3) cognitive performance effects associated with sleep inertia, to produce a 3-process applied model of human cognitive effectiveness.

The Fatigue Avoidance Scheduling Tool (*FAST*™) is based upon the SAFTE applied model. *FAST*™ was developed initially as an Air Force product under the Small Business Innovation Research program to deal specifically with Air Force scheduling issues. It is a Windows® program that estimates the average effects of various work-rest schedules on human cognitive performance by entering work and sleep data in any of several formats. Graphic plots from *FAST*™ are used later in this Manual. SAFTE and *FAST*™ are described in more detail in Attachment 2.

[7] For example, flying, driving, operating weapons, making command and control decisions.

Alternatively, there are two other world-class, quantitative models that may be used to help predict fatigue occurrence in shiftwork. One is the System for Aircrew Fatigue Evaluation (SAFE), which focuses mainly on aviation issues[8]. The other is the Fatigue Audit InterDyne™ (FAID), which focuses on estimating the risk of fatigue-induced errors[9]. FAID is authorized for use as a tool in the implementation of fatigue risk management systems in Australian civil transportation sectors (aviation, rail, highway, maritime) and military operations. It has also been used in specific implementations in the US, Canada, the UK, South Africa and South-East Asia.

Section C—Shiftwork and Safety

Biology and Shiftwork. In terms of human biology, night work is a crime against nature. We cannot see well in the dark. Our metabolism slows overnight until it reaches a low point, usually during the pre-dawn hours. In the dark, the pineal gland at the base of the brain releases the hormone melatonin which, in turn, makes us feel drowsy. At night, the likelihood compared to daytime that we will sleep when lying down comfortably with our eyes closed is very high. Our brains and bodies are designed to sleep at night and to work during the day. Thus, when an operation requires staffing 24 hours per day, 7 days per week (24/7), there is no "good" shiftwork schedule to be found. However, there are an infinite number of possible shiftwork schedules. The principle-based approach to scheduling described in this Manual constrains the infinite number to those schedules that are simple, practical to implement and least harmful to worker health, job performance and attitude. Thus, the constraints should help you produce the least-injurious schedule for your operation.

Safety and Productivity in 24/7 Operations. According to the National Sleep Foundation, people who are sleep deprived think and move more slowly, make more mistakes, and have difficulty remembering things. These negative effects lead to lower job productivity and can cause accidents. One of the leading shiftwork research centers combined the findings from numerous field studies conducted in companies engaged in 24/7 shiftwork[10]. The results of their efforts show you what to expect in terms of safety and productivity when shiftwork is used. The combined data from field studies showed that:

> "Risk [of injuries and accidents] was found to increase in an approximately linear fashion across the three shifts, ... 18.3% on the afternoon shift ... 30.4% on the night shift, relative to that on the morning shift." (8 studies; Figure 1)

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[8] Civil Aviation Authority. *Aircrew Fatigue: A Review of Research Undertaken on Behalf of the UK Civil Aviation Authority.* CAA PAPER 2005/04, Research and Safety Analysis Section, Safety Regulation Group, October 2005. (http://www.caa.co.uk/docs)

[9] http://faid.interdynamics.com/

[10] From the Body Rhythms and Shiftwork Centre, University of Wales, Swansea: S Folkard and P Tucker (2003). Shift work, safety and productivity. *Occupational Medicine*, v. 53, no.2, pp. 95-101.

“ … ‘real-job’ speed and accuracy measures are only above average between 0700 h and 1900 h; at all other times efficiency is likely to be relatively impaired, especially so during the early hours of the morning.” (3 studies; Figure 2)

There is an important caveat with respect to this and subsequent graphs concerning the relative risk of injury and accidents in industry: it is highly likely that injuries and accidents are under-reported in industry. In theory, the use of a relative risk measure accounts for that under-reporting. However, if the under-reporting pattern varies across shifts and/or across days of the week, then the correction may not be valid.

The most reliable of these graphs are those showing relative risk across 8-h morning, afternoon and night shifts (Figure 1), relative risk as a function of time on shift (Figure 4), relative risk across successive night shifts (Figure 5), and relative risk across successive morning shifts (not shown here)[11]. These risk estimates were combined into a risk-estimating formula that is presented in Chapter 5, Section C.

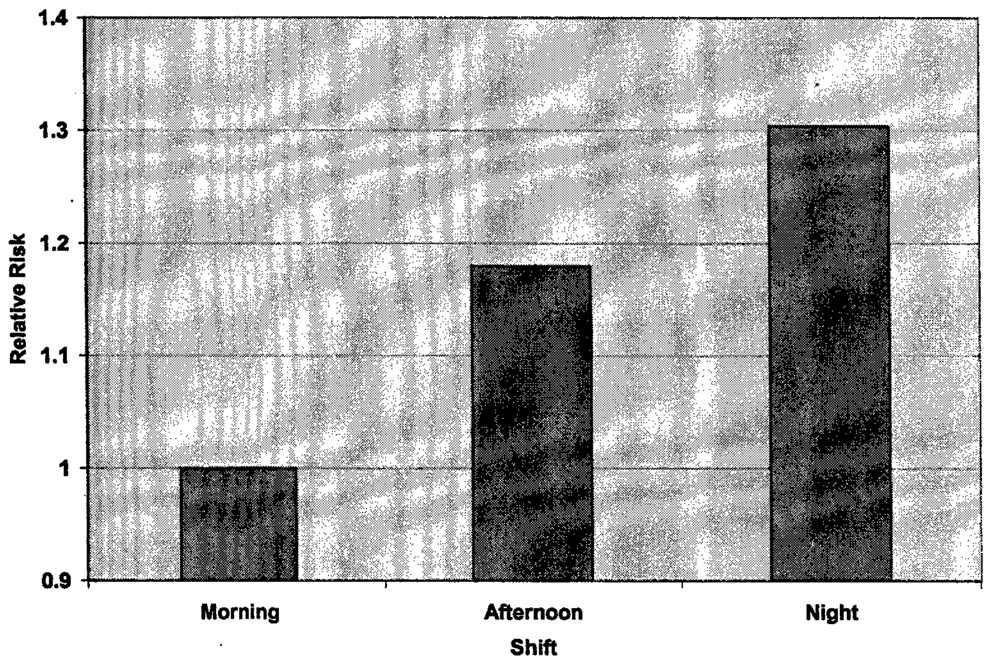

Figure 1. Relative risk of injuries and accidents across the three shifts.
Data from 8 field studies[12].

[11] S Folkard, DA Lombardi, PT Tucker (2005). Shiftwork: safety, sleepiness and sleep. *Industrial Health*, v. 43, pp. 20–23.

[12] Figures 1 through 5 were re-drawn from Folkard and Tucker, *op. cit.*

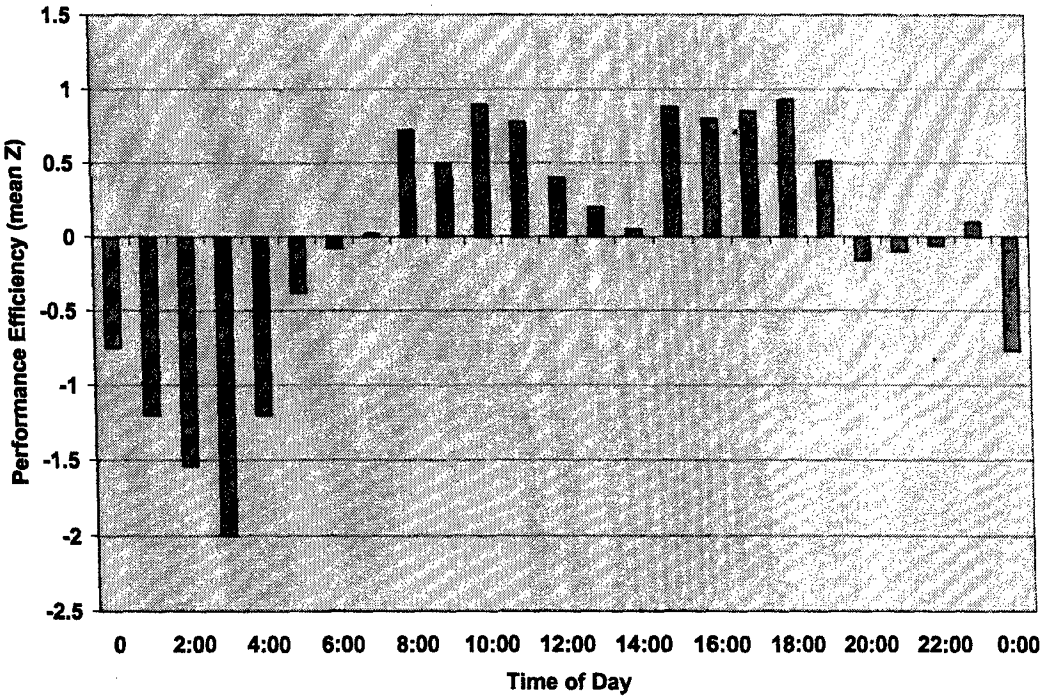

Figure 2. Relative real-job speed and accuracy measures across the hours of the day. Data from 3 field studies.

Field-study data also indicated that, in the short term, acute fatigue may be offset to some degree by work breaks (Figure 3). Following a 15-min break after 2 h of continuous work, "risk [of injuries and accidents] rose … approximately linearly, between successive breaks … risk had doubled by the last 30 min period." There was "… no evidence that this trend differed for the day and night shifts." (Of course, there is a higher absolute risk during the night shift, as shown in Figure 1). This risk pattern argues for a high frequency of rest breaks. However, if the handing-over of a task from worker to worker involves high risk, then the risk-related benefit of frequent breaks may be lost.

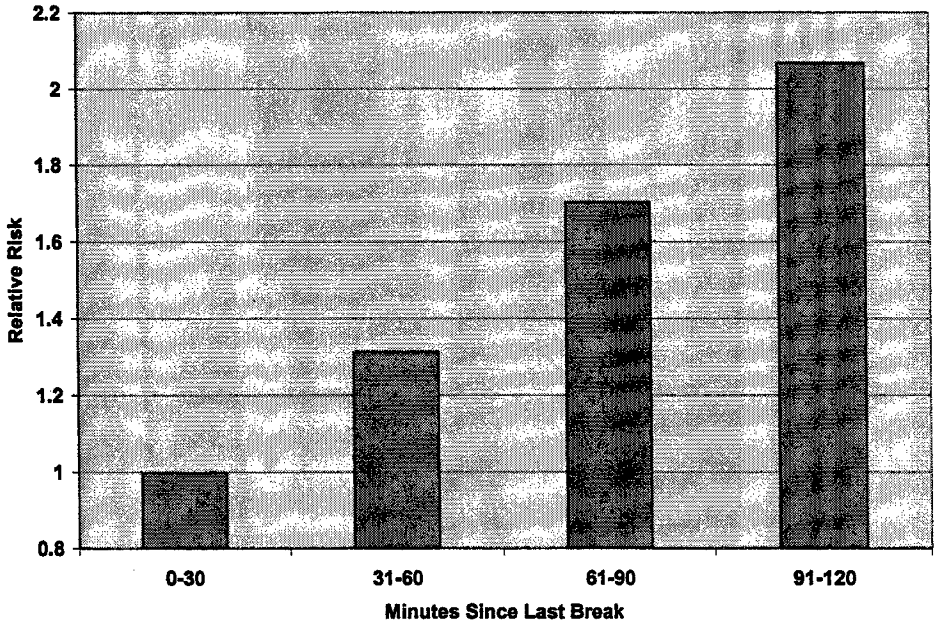

Figure 3. Relative risk of injuries and accidents during the four 30-min work periods following a 15-min break. Data from one field study.

Also according to the National Sleep Foundation, the risk of workplace accidents and automobile crashes rises for tired shiftworkers, especially on the drive to and from work. People think that opening the car windows or listening to the radio will keep them awake. However, studies show that these methods do not work. In fact, these actions should signal you that you are fatigued and need to pull over immediately. Remember, sleep can overcome you quickly when you don't want it to. If you are sleepy when your shift is over, try to take a nap before driving home. Allow 5 to 20 minutes for sleep inertia[13] to wear off, as needed. Follow these steps to arrive home safely:

- Carpool, if possible; have the most alert person do the driving
- If you are sleepy, stop to nap, but do so in your locked car in a well-lit area. Allow 5 to 20 minutes for sleep inertia to wear off, as needed.
- Take public transportation, if possible
- Drive defensively
- Don't stop off for a "night cap." Alcohol, combined with fatigue, increases the risk of a fatigue-related accident quite sharply.

These actions may often be viewed as impractical or unnecessary because night workers almost always drive home safely after their night shift. Similarly, drunk drivers almost always drive without accidents. However, just as the Air Force does not condone drunk driving, we should not condone the idea of sending a highly-fatigued driver out the gate of an Air Force Base and into traffic or a long commute on a boring highway. A recent court case provided an example of what can happen to a fatigued night worker on his way

[13] Feelings of grogginess and/or sleepiness that occur immediately after waking up.

home[14]. Nabors Drilling Co. employee Roberto Ambriz fell asleep at the wheel on Texas State Highway 490 near the city of Raymondville about 20 minutes after ending his graveyard shift in March of 1998. His pick-up truck went into the oncoming lane, striking a Dodge pick-up being driven by Martin Rodriguez. Rodriguez and his three passengers died at the scene, and Ambriz died from his injuries two days later. A decision was won against the employer for failure to train employees that work graveyard shifts about the risks of driving after working a graveyard shift.

Air Force managers should act to prevent the impracticality of the preventive actions, above, whenever possible. For example, the use of public transportation may delay the onset of daytime sleep for night workers substantially. Thus, managers should consider providing and requiring the use of a carpool with a rested, trained driver for night workers with relatively long commutes. Similarly, managers should consider providing and requiring the use of pre-drive napping quarters for night workers and fatigued workers who are ending their shifts. Managers should also consider added training sessions for night and rotating-shift workers concerning defensive and intoxicated driving.

Section D—Calendar Arithmetic for Shiftwork Scheduling

The planning of a 24/7 shiftwork schedule can be clarified in part by making some small adjustments in your thinking about the calendar. First, think of one year as being 36<u>4</u> days long. This is exactly 52 weeks: 7 days per week times 52 weeks per year = 364 days per year. Second, think of a month as being 28 days long; this is exactly four weeks: 7 days per week times 4 weeks per month = 28 days per month[15]. Third, note that there are exactly thirteen 28-day months in one 364-day year: 28 days per month times 13 months per year = 364 days per year[16]. Finally, note that there are 168 hours in a week: 24 hours per day times 7 days per week = 168 hours per week. There are 168 hours per week, 672 hours per 28-day month and 8,736 hours per 364-day year to be worked in 24/7 operations.

The numbers, above, form a cascade of factors. A factor may be defined as one of two or more numbers that divides a larger number without a remainder. The use of factors is very important in shiftwork scheduling to help provide equity and predictability in schedules. In the cases here,

- 7 and 52 are factors of 364,
- 4 and 7 are factors of 28,
- 13 and 28 are factors of 364, and
- 7 and 24 are factors of 168.

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[14] Francisca Escoto *et al. vs.* The Estate of Robert Ambriz *et al.*, Cause No. 00-81, Raymondville, Willacy County, Texas, 197th Judicial District, 16 November 2001.
[15] Memory cue: a lunar month is also 28 days long.
[16] Memory cue: there are also 52 cards in a deck, and 13 cards in each of 4 suits.

Chapter 2

NINE PRINCIPLES

The Principles. Nine principles of shiftwork scheduling are explained in this Chapter. We refer to them as "principles" in the sense that they describe the essential qualities that determine the intrinsic natures of shiftwork schedules. They are organized into the following groups:

- Principle 1, Circadian Stability: minimizing shift-lag fatigue and malaise by maintaining circadian entrainment to the local, 24-h daylight-darkness cycle; includes guidelines on sleep hygiene
- Principles of Chronohygiene
    - Principle 2, short shift length
    - Principle 3, minimum consecutive night shifts
    - Principle 4, recovery after each night shift
    - Principle 5, maximum number of free days on weekends
    - Principle 6, at least 104 days off per year
- Shiftworker Satisfaction
    - Principle 7, equity among shiftworkers for types of work days and free days
    - Principle 8, predictability of specific work and free days
    - Principle 9, good quality of time off

The idea of <u>work compression</u> arises in the discussions of several of the Principles, especially Principle 9. In the zero-sum nature of 24/7 operations, work compression is used to allow the expansion of continuous time off. In a zero-sum system, any gain within the system must be offset by an equal loss within the system. In practice, work compression means that once you arrive at work you stay there more hours. In return, you have more continuous hours off within a specified number of days or weeks or months. A common example of work compression is working four 10-hour days per week and having a 3-day weekend, instead of working five 8-hour days and having a 2-day weekend.

The Principles should be viewed as semi-related goals. It is highly unlikely that any one schedule will be able to fully satisfy all nine Principles. For example, single days off to ensure regular recovery from day and afternoon shifts, and longer, continuous periods of days off after night shifts are desirable for dealing with job-induced fatigue. However, shiftworkers rarely tolerate single days off and prefer to work longer, continuous periods to get longer, continuous periods of days off. The scheduler must balance the response to the two demands and there is no absolutely correct answer. The scheduler must decide which Principles are most important for the job at hand and for the shiftworkers' wellbeing. Participatory schedule design, involving the shiftworkers in the design process, will help the scheduler find the correct balance of emphases across the various Principles for the specific job and available workers. If there is a large number of shiftworkers, then ombudsmen from that group should be involved in participatory design.

Section A—Circadian Stability

Principle 1, Circadian Stability: Unfortunately, working and/or just being awake from midnight to dawn almost always disturbs the circadian rhythm. In very approximate terms, each "all-nighter" of wakefulness for someone who normally sleeps nights may shift the circadian rhythm about ¾ of an hour later with respect to the daylight-darkness cycle. This shift may cause the fatigue and malaise associated with jet lag and shift lag. The fatigue and malaise may be greater after the second all-nighter than after the first, and it will probably get worse.

There are two basic approaches to maintaining circadian stability in the face of night work. One is to work only at night (fixed shift) and try to invert your circadian rhythm as much as possible. To achieve and maintain an inverted circadian rhythm, you must protect yourself from bright light and sunlight in the morning after work (wear sunglasses and a hat with a visor), sleep as early as possible during the day in a very dark environment, and be exposed to bright light during the first half of the night work shift (for example, 2000 lux for 6 hours)[17].

The alternative approach is to minimize your exposure to night work, disturbing your circadian rhythm as little as possible. How many nights of work comprise the "minimum?" Ideally, as discussed below (Principle 3), there would be only single nights of work in a schedule, but this is often impractical. A more practical approach may be borrowed from the domain of jet lag. In the case of jet lag, most people's task performance is acceptable in the several days following a 3-hour-or-less time zone change. Though shift lag and jet lag are not fully comparable, we may use the 3-hour circadian shift as an upper operating limit here for shift lag. Thus, we judge a shiftwork schedule as being acceptable if there are no more than three sequential nights of work (approximately 2.25 hours of change in the body clock), and they are followed by at least three nights of sleep.

Sleep Hygiene. Keeping a stable circadian rhythm is best accomplished through good sleep hygiene. The following guidance on that subject, including Table 1, was acquired from "Strategies for Shift Workers," published by the National Sleep Foundation; the material was reorganized and augmented slightly to meet the needs of this Manual.

> Most adults need 7 to 9 hours of sleep per night. Remember, when you are not getting the sleep you need, you are at risk...and so are those around you. Inadequate sleep increases your risk for falling asleep at the wheel, accidents on the job, and problems at home. There are several steps a shiftworker can take to successfully fall asleep and stay asleep at home. The key is to make sleep a priority! Set the stage for sleep even though it might be broad daylight outside. Prepare your body and mind for sleep. If you are on the night shift, wear

[17] VL Revell, CI Eastman (2005). How to trick Mother Nature into letting you fly around or stay up all night, *Journal of Biological Rhythms*, v. 20, no. 4, pp. 353-365.

wraparound dark glasses and a billed hat on your way home from work to help keep morning sunlight from activating your internal "daytime" clock. Follow bedtime rituals and try to keep the same sleep schedule — even on weekends. Go to sleep as soon as possible after work.

At home, ask family and friends to help create a quiet and peaceful setting during your sleep time. Have family members wear headphones to listen to music or watch TV. Ban vacuuming, dish washing, and noisy games during your sleep time. Put a "Do Not Disturb" sign on the front door so that delivery people and friends will not knock or ring the doorbell. Schedule household repairs for after your sleep time.

Talk with family members and friends about your concerns. With their help, you can schedule special times to share with a spouse, children and friends. Remember that sleep loss and feeling at odds with the rest of the world can make you irritable, stressed and depressed. As one expert puts it, "Blame the shift work — not your kids!"

Caffeine. Some additional thoughts about caffeine are in order here. Caffeine is the wake-promoting stimulant of choice in our society and, as such, it is often in a non-optimal manner. Fortunately, caffeine can be a shiftworker's ally. Unfortunately, the dividing line between smart, optimal, tactical caffeine use and caffeine misuse is narrow.

Used only when needed and with reasonably good sleep beforehand, caffeine can be a highly effective fatigue countermeasure. If too much is used chronically, then its alerting benefits are lost through habituation. This "abuse" limit is about 200 to 250 milligrams (mg) per day: about 1 mug of coffee. However, caffeine affects people's sleep differently. For some, even small amounts can cause problems sleeping. For others, caffeine has no apparent detrimental effect on sleep. Chronic overuse may also cause dehydration, nervousness and irritability.

Caffeine may be taken in liquid (coffee, tea, colas) or pill forms. Once absorbed from the stomach, its half-life in the blood stream is about three to five hours. A cup (not a mug) of coffee provides about 100 mg of caffeine, while SmithKline Beecham's Vivarin® and Bristol-Myers Squibb's NoDoz® pills each contain 200 mg of caffeine.

Certain over the counter (OTC) pain relievers at your local pharmacy also contain caffeine, so check the labels. The "active ingredients" part of OTC drug labels will tell you the caffeine dose in mg. For example, a brief period of study several years ago at a local pharmacy showed that:

- Aspirin Free Excedrin® and Excedrine Migraine® contained 65 mg of caffeine
- Bayer's Vanquish® Pain Reliever contained 35 mg of caffeine, and
- Goody's® Headache Powder contained 32.5 mg of caffeine.

Table 1. Tips for successful shuteye for shiftworkers, from the National Sleep Foundation.

BEDTIME RITUALS
Take a warm bath
Don't "activate" your brain by balancing a checkbook, reading a thriller, or doing other stressful activities
TEMPERATURE
Lower the room temperature; a cool environment improves sleep
LIGHT
Darken the bedroom and bathroom
Install light blocking and sound absorbing curtains or shades
Wear eye shades while sleeping
Wear wraparound dark glasses and a billed hat on your way home from work to keep morning sunlight from activating your internal "daytime" clock
SOUND
Wear ear plugs
Use a white noise machine or a fan to block out noises
Install carpeting and drapes to absorb sound
Unplug the telephone
FOOD
Avoid caffeine at least five hours before bedtime
Avoid using alcohol as a sleep aid; while you may feel sleepy at first, alcohol actually disturbs sleep
Eat a light snack before bedtime; don't go to bed too full or too hungry
EXERCISE
If you exercise at the workplace, do so at least three hours before you plan on going to bed. Otherwise, exercise after you sleep. Because exercise is alerting and raises the body temperature, it should not be done too close to bedtime.
NAPPING
Naps as short as 20 minutes can be helpful. They can maintain or improve alertness, performance and mood.
The evening or night worker should try to take a nap before work
Napping in the workplace is especially effective for workers who need to maintain a high degree of alertness, attention to detail, or make quick decisions
In situations where the worker is working double shifts or longer, naps at the workplace are even more important
Some people feel groggy or drowsy after a nap. These feelings usually go away within 1-15 minutes, while the benefits of the nap may last for many hours.
SEEKING MEDICAL HELP
If you have trouble falling or staying asleep, or you wake up feeling unrefreshed, you may be suffering from insomnia or sleep apnea, serious conditions that should be treated. Be cautious about self-treating the symptoms of these conditions.
A physician can suggest safe and effective treatments. Sleep specialists have training in sleep medicine and can both diagnose and treat a variety of sleep disorders. Many sleep specialists work at sleep centers.

Section B—Principles of Chronohygiene[18]

These five Principles were conceived in the 1970s in Europe, and they focused primarily on 8-h shifts with rapid rotations. They are amended slightly here to deal with the advent of work compression (in other words, the increasing preference for 12-h shifts).

Principle 2, Short Shift Length: Emphasize a shift length of no more than 8 hours, with the exception of using a 12-h shift length for jobs with low physical and emotional work stresses[19]. Recall the study mentioned above that combined the findings from numerous field studies conducted in companies engaged in 24/7 shiftwork. Those researchers combined data from three field studies and noted that "...risk [of injuries and accidents] increased in an approximately exponential fashion with time on shift such that in the twelfth hour it was more than double that during the first 8 h" (Figure 4).

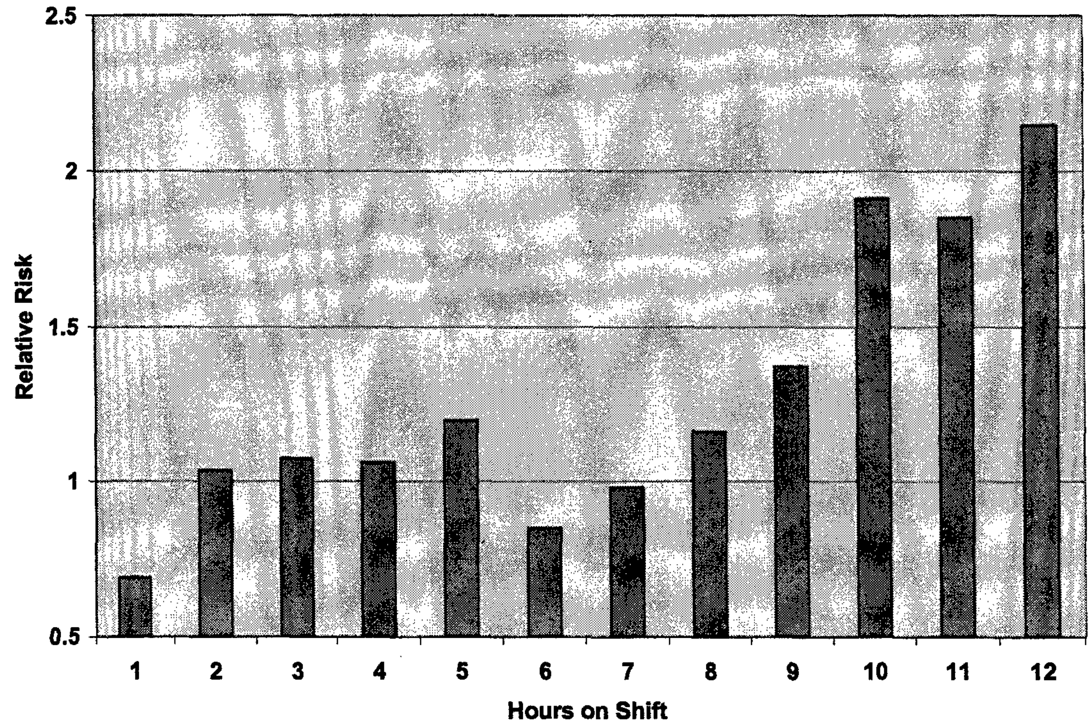

Figure 4. Relative risk of making of injuries and accidents as a function of time on shift. Data from four field studies.

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[18] Adapted from G Hildebrandt (1976), *Chronobiologia*, v. 3, no. 2, pp. 113-126.

[19] Low-stress jobs do not include jobs with high vigilance performance requirements. Vigilance performance may be defined as remaining alert for a very rare, but very important, occurrence that is embedded in a background of frequent, similar, unimportant occurrences. Examples usually include jobs with high "monitoring" requirements, such as security guard duty, security scanning of the baggage of commercial airline passengers, and quality control inspection in manufacturing.

This Principle is addressed in more detail in the discussion of the shift length component of shiftwork scheduling (Chapter 3). In passing though, you should realize that this is not a particularly new observation. It formed a part of the basis for a general reduction of the workday length from 12 hours to 8 hours in the first half of the 1900s. In fact, a landmark 1947 book on fatigue summarized the earliest systematic data on the subject:

> Beginning his observations in 1816, and continuing for a period of 12 years, Robert Owen found that a 10½-hour day was as productive as a 16-hour day in his cotton mills. In 1893-1894, Mather and Platt discovered the 48-h week gave the same annual output as a 53- or 54-hour week in the Salford Iron Works. From 1899 to 1901, Abbé found an 8-h day gave 3 percent greater total earnings than a 9-hour day at the Zeiss Optical Works. (S.H. Bartley and E. Chute, *Fatigue and Impairment in Man*, McGraw-Hill, 1947, p. 175)

The lessons here are (1) that too much time spent at work is highly likely to impair productivity, and (2) that 8 hours appears to be the maximum workday length to sustain quality productivity across days, weeks, months, and years.

Principle 3, Minimum Consecutive Night Shifts: Minimize the number of consecutive night shifts. Preferably, there should be only single night shifts in a shift plan. The basic reasoning here is that productivity goes down and safety risk goes up across successive nights. Looking across data from 7 studies of night shifts, the combined-field-studies analysis concluded that "...risk [of injuries and accidents] was ~6% higher on the second night, 17% higher on the third night and 36% higher on the fourth night" (Figure 5). This was compared to successive day shifts in 5 of the 7 companies, where the increases were "... ~2% higher on the second morning/day, 7% higher on the third morning/day, and 17% higher on the fourth morning/day than on the first shift." Thus, the relative penalty for successive night shifts, compared to successive day shifts, was a factor of about 2.5 time greater safety risk.

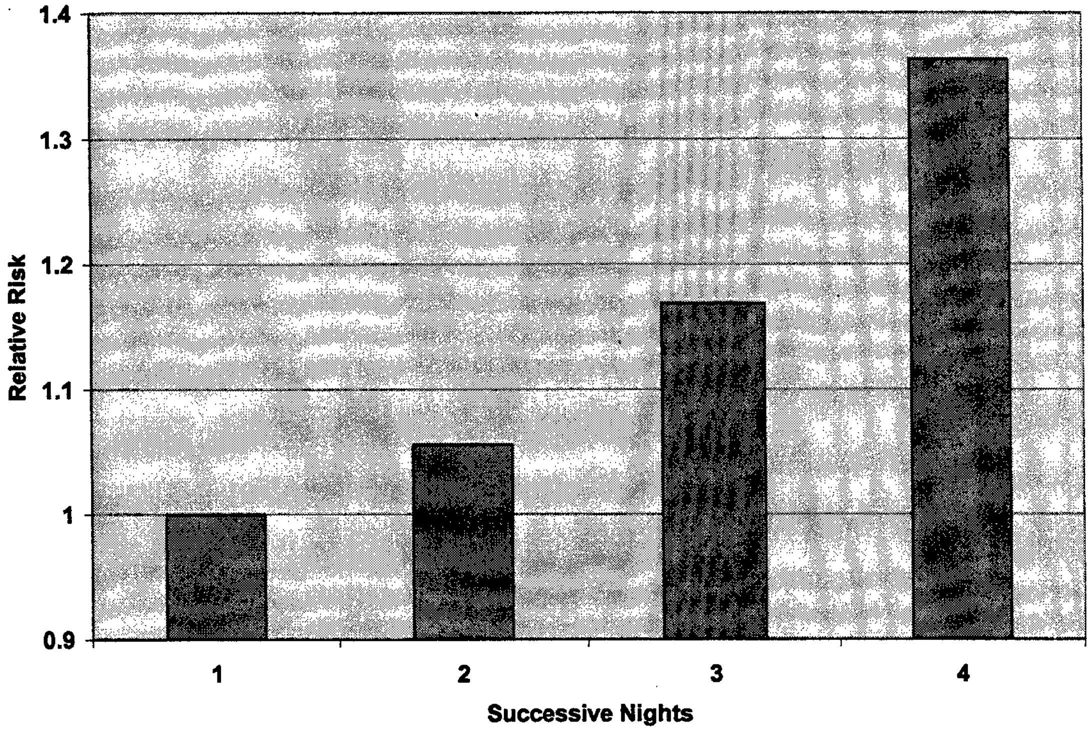

Figure 5. Relative risk of injuries and accidents as a function of successive night shifts. Data from five field studies.

Principle 4, Recovery After each Night Shift: Each night shift should be followed by 24 hours off. This Principle incorporates the interesting philosophy that recovery from night work should occur on days off. This philosophy makes good sense in terms of physiology and safety. The worker needs quiet time in which to repay the sleep debt incurred during night work. Also, the fatigued worker may be a safety hazard to self and co-workers.

The alternatives to recovering from night work on a day off are (1) to work a double shift (the night shift plus the immediately-following day shift); or, assuming 8-h shifts, (2) to rotate to the swing shift on the afternoon of the day on which the night shift ended. From the materials presented so far in this Manual, you should realize that both alternatives would produce a very fatigued worker. If the worker does not have a safety-sensitive job, these alternatives may be acceptable occasionally, but you should remain aware that the worker is highly likely to make many fatigue-induced errors on the job.

The philosophy needs careful attention with respect to the quality of time off (also, see Principle 9). Recall that in a shift plan a free day, or a day off, is defined as a day on which no shift starts. Thus, the classic night shift worker who starts a shift at 2300h and finishes at 0700h the next morning is credited with a free day even though the first 7 hours of that day were taken up by work, and the worker is either sleeping much of the day or sleepy all day. Though it is usually specified in shiftwork plans as a day off, you should classify at least the first day off after one or more successive night shifts as a "recovery" (R) day, and not credit the worker with a day off. For example, there is a very

useful 4-crew plan with 12-h shifts that calls for 2 day shifts, 2 night shifts, and 4 days "off" (DDNNOOOO). It would be more accurate to think of this plan as 2 day shifts, 2 night shifts, 1 recovery day, and 3 days off (DDNNROOO).

The philosophy also needs careful attention with respect to employer liability for automobile accidents involving their shiftworkers. It is "case law" (law based upon judicial decisions and precedents rather than on statutes) in the United States that the employer may be held liable for the results of these kinds of accidents[20]. In theory, supervisors of shiftworkers may be sued as a result of the shiftworkers' traffic accident. The employer may be able to reduce liability by implementing recommendations of the National Institute of Occupational Safety and Health (NIOSH), including the provision of training or awareness programs for new shiftworkers and their families, and health care and counseling services for shiftworkers[21].

The free-day-recovery philosophy should be considered, with care, at remote work sites. At remote sites, shift systems and plans are often engineered such that long free periods are available. During these free periods, workers may depart the remote site. If the worker begins the free period after one or more night shifts, he or she is not vigilant enough to operate an automobile for a long period. Deaths and injuries occur in single-vehicle, run-off-the-road accidents that are created by travel from these remote work-site conditions. Management may be able to reduce liability in this situation by adopting the philosophy of scheduling the free periods after D or S shifts or by requiring a sleep period between the end of the night shift and driving.

Principle 5: Maximum Number of Free Days on Weekends. This Principle and Principle 6, below, focus mainly on the issue of perceived inequity with weekday-only workers, who have 104 free weekend days per year (assuming that they work Monday through Friday). Many shiftworkers, especially those on active military duty, express dissatisfaction with the fact that they do not have the free weekends that are available to their peers who have weekday-only jobs. The shiftwork scheduler must be aware of this issue and must be able to quantify and discuss the issue without equivocation.

There is at least one potential pitfall when the scheduler deals with this issue: more free weekend days become available in the schedule when one compresses work by using 12-h shifts instead of 8-h shifts. (Work compression is discussed under Principle 9, below.) Thus, the scheduler may face pressure from shiftworkers to implement 12-h shifts to satisfy the workers when it is, in fact, an inappropriate shift length selection for the workers' jobs with regard to risks of making on-the-job errors. An alternative approach is to use a complex schedule with 8-hour shifts on weekdays and 12-hour shifts on weekends. This approach reduces the weekend work demand by one-third, compared to working straight 8-hours shifts; reduces the risks associated with longer shifts, compared

[20] For example, see the $5,950,000 award in Francisca Escoto *et al. vs.* The Estate of Robert Ambriz *et al.*, Cause No. 00-81, Raymondville, Willacy County, Texas, 197th Judicial District, 16 November 2001.

[21] *Plain Language about Shiftwork*, NIOSH (DHHS) Publication No. 97-145.

to working straight 12-hour shifts; and provides an intermediate level of work compression. A version of this complex schedule is shown, below, in Section G.

The scheduling component called "alignment" is the implementation of Principle 5, and is discussed in Chapter 4. There are two manners in which you may create a schedule that maximizes the number of free weekend days. First, use a shift plan cycle length that is a multiple of 7 days. Align that plan with the days of the week so that good-quality days off (not recovery days) fall on one or more weekends. Because the shift plan cycle length is a multiple of the length of the week, the alignment of the shift plan with the days of the week will never change. Thus, those specific free days will always fall on those specific weekend days.

For example, there is a shift plan used by many USAF Security Forces operations called the "Panama" or "every-other-weekend-off" plan. This plan is presented in more detail in Chapter 4. The shift plan cycle length is 14 days (a multiple of 7) and it uses nominal 12-h shifts (without overlap; see Chapter 4). The rotation between day and night shifts usually occurs once every 28 days (a "slow" rotation). Working days or nights, you follow this work-rest sequence for each 14-day cycle: 2 days on, 2 days off, 3 days on, 2 days off, 2 days on, and 3 days off. The 3 days on and the 3 days off both fall on Friday, Saturday and Sunday, giving you every other weekend off. (The Fridays "off" during the night shift month should be viewed as recovery days.) Thus, across 364 days (26 of these 14-day cycles), you would have 26 weekends, or 52 weekend days, off per year. That is only half the number recommended by Principle 5. Thus, the plan is quite weak in this regard and you should expect shiftworker complaints about inequity with people with weekday jobs and 52 weekends off per year.

The second approach is to use a shift plan cycle length that is not a multiple of 7 days. Because the shift plan cycle length is not a multiple of the length of the week, the alignment of the shift plan with the days of the week will change across weeks, but in a predictable manner. You need a different number of days than the shift plan's cycle length across which to calculate the number of weekend days off per year. This number is the product of the shift plan cycle length and 7 days, the length of a week.

For example, recall the 4-crew plan with 12-h shifts that calls for 2 day shifts, 2 night shifts, 1 recovery day, and 3 days off (DDNNROOO). The shift plan cycle length is 8 days. However, with respect to the plan's alignment with weekdays, the cycle length is (8 days per cycle x 7 days per week =) 56 days. If this plan starts on a Monday, then it will start on a Monday again on day 57. The alignment of this plan with the days of the week is shown as an example in Chapter 4 (Table 7). There are 6 weekend days off per 56-day period in this plan. The 56-day period is not a factor of the 364-day year: there are 6.5 of these periods in a 364-day year. Thus, the number of free weekend days in one 364-day year for this plan is (6.5 periods per year x 6 weekend days off per period =) 39 weekend days off per year. This plan is even weaker in this regard than the Panama plan and, again, you should expect shiftworker complaints about inequity with people with weekday jobs and 52 weekends off per year.

Principle 6: At Least 104 Days Off per Year. We considered just weekend days off under Principle 5. Under Principle 6, we examine total numbers of days off. This principle focuses mainly on the issues of perceived equity with weekday-only workers and chronic fatigue. Weekday-only workers have 104 days off per year, on their 52 weekends. In both the Panama plan and the DDNNROOO plan, each crew is assigned to work a shift on half of the days in a cycle because these plans are 4-crew solutions to the 24/7 work demand. By extension, the crews will be "off" on half of the days in a year, or 182 total days off per year. If we take the DDNNROOO plan as a model and consider ¼ of the days off per year to be recovery days, then both plans allow about 136 good-quality days off per year. This compares quite favorably with the 104 days allowed for the weekday-only worker.

A senior manager or an accountant may look at the 182 or 136 days off per year, above, compare them to the "normal" 104 days off per year number that is used to estimate manning levels in business plans, and complain that the shiftworkers in 4-crew systems "have it too easy." This complaint reveals ignorance about the strains induced in humans by the stresses of shiftwork. Because the shiftworker is exposed repeatedly to cumulative fatigue and is thus at high risk for developing chronic fatigue and the illnesses associated with chronic shiftwork (Chapter 1), the shiftworker must be given many more days off than the weekday-only worker. The ratio of 136 days to 104 days gives about 30% more days that the weekday-only worker, a number that may satisfy the criterion of "many more days."

To save personnel costs, a planner may decide to use only 3 crews to meet the demand of 24/7 operations. This increases the weekly work demand on the shiftworker to an average of 56 hours per week (see "Number of Crews" in Chapter 4) and requires each crew to work 2/3 of each 364-day year. This work requirement allows only about 120 days off per year and only about 90 good-quality days off, fewer than the days off allowed for the planner and other weekday-only workers. This is a sure recipe for invoking high levels of cumulative fatigue and high risks of chronic fatigue among the shiftworkers. As a result, there will be elevated numbers of personal days and sick days taken each year and poor morale and poor personnel retention. This is a case where poor planning, due to ignorance of the effects of shiftwork on humans, leads to poor system performance. As shown in Chapter 4, the 4-crew solution provides the optimal balance between the work, health, social, and safety demands placed upon the shiftworker and the personnel cost to the employer for safe and productive system operation.

Section C—Shiftworker Satisfaction

Principle 7, Equity: All shiftworkers should be exposed to equal demands for long duty days, night work and weekend work, and should also have equal access to good quality time off and weekends off. Principles 5 and 6 focused on equity with weekday-only workers. This Principle focuses on equity among the shiftworkers, themselves. As noted in Chapter 1, shiftwork schedules often include day-to-day and week-to-week, last-minute scheduling and fail to account for the simple arithmetic of the calendar and its cycles. It is highly unlikely that a last-minute approach to shiftwork scheduling will

produce equity across shiftworkers in the demands and accesses noted above. In the unlikely event that equity does exist at the level of arithmetic, there is such confusion among shiftworkers and their scheduler that there is no perception of equity. The likely results of inequities or perceived inequities across shiftworkers are poor morale and poor personnel retention. Equity may be achieved by working through the nine shiftwork scheduling components described in Chapter 4. The sequence of decisions that must be made concerning the components forces you to develop an equitable schedule.

Perceived equity may be achieved by participatory design and by education. When a new shiftwork schedule is to be designed and implemented, the shiftworkers who will work the schedule should be included as members of the design team. These shiftworker-designers will develop "buy-in" for the schedule possibilities that they help design. They may serve as ombudsmen between the design team and the remainder of the shiftworkers, helping to explain the design choices and, especially, pointing out the equities guaranteed by each schedule possibility. They may even lead a voting process among the shiftworkers to decide which of several possible schedules is best for the majority of the shiftworkers. When new shiftworkers enter an existing shiftwork schedule, either management or shiftworker ombudsmen should educate the new shiftworkers about the decisions underlying the schedule design and, especially, its equities.

Principle 8, Predictability: The schedule is so easy to understand that workers may apply simple arithmetic to predict their actual work and free days well into the future. One shiftwork consultant found schedule predictability to be the third-highest concern of shiftworkers[22]. Day-to-day and week-to-week, last-minute scheduling and failure to account for the simple arithmetic of the calendar and its cycles generates confusion among shiftworkers about their future work and free days. It also causes management to assign a front-line or middle manager as a "scheduler" to make sure that every job is filled every day. These are both expensive propositions. In the first case, the shiftworker who cannot accurately predict their work and free days will suffer from poor morale and is more likely to quit the job than the shiftworker who can predict work and free days. In the second case, a person with good technical and/or management skills is paid to spend their full time trying to fill work periods to cover multiple positions and multiple shifts every week. This individual should be a direct contributor to productivity, not a financial burden on overhead.

When a schedule is predictable and the shiftworker asks a question such as, "My brother, whom I have not seen in 3 years, will be in town on the 15th and 16th of next month. Will I be working on those days?" The answer should be as simple as counting the number of days or weeks until then and applying the shift plan to that sequence of days. The answer should <u>not</u> be a statement from management such as "I don't know yet; I'll tell you in a couple of weeks."

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[22] RM Coleman (1995). *The 24-Hour Business*, American Management Association, New York NY, 1995, p. 95.

When a schedule is predictable, there is no front-line or middle manager assigned to be a "scheduler." This is a large cost savings for management: in today's economy, the fully-burdened cost for a middle manager might be $150,000 per year or more. Shiftworkers and managers all know a predictable, repeating schedule from any given date to, theoretically, infinity. The schedule must only be managed for exceptions such as sick days, vacation days and holidays. These exceptions may be handled by existing managers, just as in the world of weekday-only work.

Principle 9, Good Quality of Time Off: This may be the primary concern of shiftworkers[23]. Shiftworkers and weekday-only workers tend to prefer schedules with long, continuous periods of time off. Such work schedules are perceived as being "good" schedules. For example for weekday-only workers in the United States, there are two popular types of work compression. One is the "10-hour day" schedule in which the 40-hour work week is completed in 4 days, allowing 3-day weekends. The other is the "every-other-Friday-off" schedule in which there are eight 9-hour work days and one 8-h workday across a 2-week period. This allows every other weekend to be a 3-day weekend.

These weekday schedules illustrate the important point that, because of the zero-sum nature of 24/7 operations, work compression is needed to allow the expansion of continuous time off. In a zero-sum system, any gain within the system must be offset by an equal loss within the system. For example, you may work (6 shifts x 8 hours per shift =) 48 hours in 8 days in the shiftwork plan called the "Metropolitan *rota,*" and have 2 days off:

DDSSNNOO

where D is a day shift, S is a swing shift, N is a night shift, and O is a day off. Or, you may work (4 shifts x 12 hours per shift =) 48 hours in 8 days and have 4 days off:

DDNNOOOO

Note the difference in the number of consecutive days off. Why does this happen? The difference in continuous time off, 4 days *vs*. 2 days, is due to a faster <u>rate</u> of work on the work days within the plan:

- With 8-h shifts, you work 48 hours in 6 work days, a rate of 8 hours per day
- With 12-h shifts, you work 48 h in 4 work days, a rate of 12 hours per day
- The ratio of 12 hours per day to 8 hours per day gives a 1.5 times faster work rate

When you move from 8-h to 12-h shifts, the work that would have taken 6 days (144 hours) will now be accomplished in (144 hours ÷ 1.5 =) 96 hours (4 days), leaving the remaining 96 hours (4 days) in the 8-day cycle for continuous time off.

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[23] *Op. cit.*, pp. 86-87.

Because Registered Nurses (RNs) in the United States are in high demand and relatively short supply, they tend to work only 12-h shifts in hospitals. Even though the statistics cited earlier show that error rates rise sharply after the 8th hour of work, RNs request and are granted the higher quality time off available with 12-h shifts. Is this a "bad" idea? Perhaps not. Review the nature of chronic fatigue as defined in Chapter 1, Section B. The RN has a stressful, fatiguing job. It is likely that higher quality of time off reduces the likelihood of chronic fatigue occurrence. Unfortunately, no research data have been collected with respect to this idea.

The optimal number of consecutive days off in a shiftwork schedule depends upon the work environment and the consideration of recovery days. In the military, there is the issue of the length of a pass. For example,

> A regular pass period (non-duty days) for units on non-traditional work schedules (alternate or compressed work schedules [and shiftwork]) may not exceed the 4-day special pass limitation. (Par. 8.2.3, AFI36-3003, 15 Feb 2005)

It is possible that regular periods of four consecutive days off may be optimal for shiftworkers. The desire for 3-day weekends in weekday-only workers suggests that these non-shift-workers need three consecutive days off. By extension, shiftworkers may need more than three consecutive days off. However, given too many days off, workers are more likely to partake in excessive leisure or additional-work activities and return fatigued to their primary job. Shiftworkers may seek 12-h shifts so that they may work at second jobs. Obviously, the risk for compounding fatigue is substantially increased by the demands of the second job.

Chapter 3

NINE COMPONENTS

The Components. Nine components of shiftwork scheduling are explained in this chapter. We refer to them as "components" in the sense that they generate the minimum number of decisions required to specify completely the composition of a shiftwork schedule. Work scheduling generally starts with considerations of how best to use people and time. "People" means the number of crews needed to cover the 24-hour, 7-day per week (24/7) work demand; and the employment ratio needed to cover vacations, holidays, sick time, administrative time, and additional duties. "Time" means the type of shift rotation (fixed, rapid or slow) and the length of the shift. The components are organized into the following groups:

- *People*
    - Number of crews, the optimal number being 4
    - Employment ratio calculation, taking into account holidays, annual leave, sick leave, training time, etc.
- *Time*
    - Shift type, including discussions of fixed *vs.* rotating shifts and forward (clockwise) or backward (counterclockwise) directions of rotation
    - Shift length, especially 8-h *vs.* 12-h shifts, and shift overlap
- *Basic Structure*
    - Shift system, the ratio of workdays to free days (XnW:YnF)
    - Shift plan (*rota*), the sequence of workdays and days off within a shift system; for example, DDSSNNOO
- *Interactions*
    - Shift differentials in terms of different hourly pay rates or different shift lengths across day, swing and night shifts
    - Alignment of workdays and days off with weekends
    - Shift change times, especially when to begin the morning shift to allow as many shiftworkers as possible to sleep well at night

A note about terminology: a shift plan is a specific sequence of work and free days within a shift system, organized around a shift type, a nominal shift length such as 8 or 12 hours and a nominal number of crews. The structures of shift plans allow direct comparisons among plans. A shift schedule includes the shift plan and other schedule components that are specific to the work domain. These include the employment ratio, shift overlap, shift differentials, alignment with weekends, and shift change times.

Section A—People

Generally, the first question asked by the shiftwork scheduler, is, "Do I have enough people?" This question must be answered by considering and making decisions about two scheduling components: the number of crews that you will use, and the minimum employment ratio that you need to support those crews.

Component 1, Number of Crews. In regular, 24/7 commercial and routine military operations, the number of crews used should be greater than the number of shifts per day so that at least one crew is off each day. This is not always true in combat and is almost never true in maritime operations. In these situations, every crew works every day.

It is natural to think that shift length sets the work demand for shiftworkers. However, this is not the case in regular schedules. The number of crews that you decide to use sets the work demand in a regular schedule. The number of crews defines the average yearly, weekly, and daily amounts of time worked by an individual. Each year provides (364 days per year x 24 hours per day =) 8,736 hours to be worked in continuous operations. Each crew must work their proportional share of the year (Table 2). If one specifies four crews, then each in the crew must work 2,184 hours per year, an average of 42 hours per week and an average of 6 hours per day (across all days of the year; this is <u>not</u> shift length). Note that among all numbers of crews shown in Table 2, the 4-crew solution most closely approximates the usual work demand placed on weekday-only workers.

Table 2. Average work demands in regular schedules for different numbers of crews and weekday-only workers, in hours (this is not shift length).

Crews	Per Year	Per Week	Per Day
2	4368	84	12
3	2912	56	8
4	2184	42	6
Weekday-only Workers	2080	40	5.7
5	1747.2	33.6	4.8
6	1456	28	4
7	1248	24	3.4

It is also natural to think that work demand changes in a simple, straight-line manner when the number of crews changes. However, this also is not the case. When you plot the numbers in the "per week" column of Table 2, you can see the relationship between the average amount of time an individual works and the number of crews used is not a straight line in regular schedules (Figure 6). Because the line is curved, changing the number of crews may change related items such as staffing and payroll in unexpected ways. The 4-crew solution provides the optimal balance between (1) the work, health, social, and safety demands placed upon the shiftworker (in terms of hours worked per unit time; the y axis in Figure 6) and (2) the personnel cost to the employer for safe and productive system operation (in terms of the number of crews to be employed; the x axis in Figure 6). The personnel costs for the employer differ primarily in overhead paid per employee, not in direct pay for hours worked.

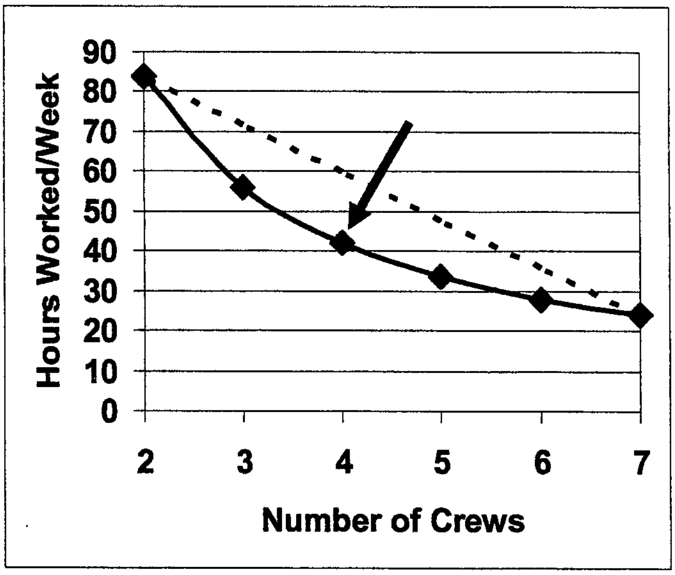

Figure 6. The actual relationship from Table 2 between the average amount of time a crew works and the number of crews (solid line) in regular schedules, and the intuitive straight-line relationship (dotted line). The arrow indicates the optimal balance between the work demand placed on the crews (hours worked) and personnel costs for crews (number of crews).

The 4-crew solution, with an average 42-h work week makes good sense for regular shiftwork scheduling. Crews work, for example, 26 weeks at 40 hours per week and 26 weeks at 44 hours per week. Often, the Fair Labor Standards Act (FLSA) will force the payment of overtime for the 44-h weeks. This amounts to 10% overtime for half of the weeks in the year, or 5% total overtime for the year. At an overtime rate of 1.5x, this means an increased total cost in worker pay of 7.5% for the year. In many cases, this cost may be offset by the savings provided by needing no scheduler and by increased retention (reduced turnover).

With respect to costs of labor, the following observation was made by Rainer Guttkuhn of Circadian Technologies, Inc.

> Once in a while we encounter environments with 3-crew schedules to cover a 24/7 operation. In most cases, one would think that running a 4-crew system would be more cost effective:
>
> - With a 3-crew system each employee works an average of 56 hours a week (3 crews x 56 hours = 168 hours of operation per week).
> - Under the federal overtime rule, 56 hours of work have to be compensated with 64 hours pay [40 hours at normal pay and 16 hours at time-and-a-half, or 40 h + 24 h].
> - If we assume the hourly rate to be $20 we get 3 crews * 64 hours * $20 * 52 weeks = $199,680 per year in wages to operate one position around the clock.
> - With a 4-crew schedule the average work hours per week go down to 42 (4 crews x 42 hours = 168 hours of operation per week).

- With a 12-hour schedule the pay would come out to be 44 hours per week on average.
- With these numbers the 4-crew system would cost: 4 crews * 44 hours * $20 * 52 weeks = $183,040 in wages per year in wages for the same position, or $16,640 less than the 3-crew system.
- Unless your cost of having a person on the payroll (health care, training, equipment) is more than $16,640 per year, it is likely to be more cost effective to run a 4-crew system.

But this only holds true under certain conditions.

- If your overtime rules include overtime pay on weekends, it might well be that a 4-crew system won't realize enough savings in wages to justify a 4th crew.
- Also, with one recent client the issue was with the fluctuating nature of the business. It was quite common to downscale from a 7-day operation to a 6-day or 5-day operation. With a 3-crew system operating 5 days (5 days * 24 hours = 120 of operation) each person would still work 40 hours a week. Going down to 5-days with 4 crews would results in very lean and probably unacceptable pay checks for the employees (120 hours of operation / 4 crews= 30 hours per crew)

While 4-crew systems are far more common these days, there are still some circumstances where 3-crew systems or 3-crew systems with temp support work better. But 3-crew systems put quite a strain on the work-life balance of the employees and may cause higher fatigue, lower moral and ultimately increased absenteeism and turnover. The higher demands of 3-crew systems could also pose a safety problem due to the overworked employees. (*24/7 Business Insider*, 2 Nov 2005, Issue 156, Circadian Technologies, Inc.)

Component 2, Employment Ratio. The most prevalent cause of shiftwork schedule problems may be management's failure to calculate the employment ratio and then to assure the availability of enough qualified shiftworkers to meet the 24/7 work demand. Employment ratios make allowances in scheduling for holidays, sick leave, annual leave and other administrative and training time. Staff strength must be at a level greater than the minimum staff needed for all crews on any given day. An employment ratio is a number greater than 1 that may be calculated as, for example:

$$\text{ratio} = (364 \text{ work} + 10 \text{ hol} + 14 \text{ ann} + 14 \text{ sick} + 14 \text{ tng}) \div 364 \text{ days per year}$$
$$\text{ratio} = 416 \text{ days} \div 364 \text{ days}$$
$$\text{ratio} = 1.14$$

where there are 364 days to be worked (work), 10 holidays per year (hol), 14 days of annual leave (ann), 14 days of sick leave (sick), and 14 days of training (tng).

Staffing may then be calculated as the product of the minimum number of people for a single crew, the number of crews required, and the employment ratio. If the minimum crew is ten people and four crews are needed, then staffing is:

10 workers per crew x 4 crews x 1.14 = 46 workers

where the quotient, 45.6 workers, is rounded up to 46 workers to avoid the bother of hiring six tenths of a worker.

There are many cases in the military in which training is so demanding of shiftworkers' time that a 4-crew solution seems impractical. A solution to this problem is shown in Chapter 4: use five crews. The question remains, "At what point do I decide that the employment ratio is too big, and that I should just use a 5-crew solution?" The answer depends upon the decision criterion that you select. If the criterion is worker pay, then the differences between the direct-plus-overhead costs for the 4-crew and 5-crew solutions may be calculated, with reference to Table 2 and Chapter 4 for direct costs for hours worked per year. If the criterion is worker, system or public safety, then the 5-crew solution is probably the way to go.

Replacing Shiftworkers. Too often, it is necessary to fill open slots in crews because of shiftworkers' holidays, vacation, sick leave, and training. There are two replacement options: use a shiftworker or use a day worker. With each method, the shiftwork schedule of the individual moving into the open slot must be considered with care. Replacement by a shiftworker means that a shift or night worker on another crew switches crews, and switches schedules, to fill the empty slot. The main concern when using a shiftworker is that the worker has had at least 24 hours off since the last night shift, or at least 16 hours off since the last day or swing shift. Also, the additional shift(s) should not cause the worker to work more than a total of about six consecutive days.

Replacement by a day worker means that an individual not on this (or any other) shiftwork or night work schedule fills the empty slot. If the individual has been off duty for at least 24 hours prior to the replacement, he or she has most likely operated on a day-awake, night-asleep schedule. The main concern for the day worker is that the additional shift(s) should not cause the worker to work more than a total of about six consecutive days.

For both kinds of replacements, as they continue to work with one crew and then another, the scheduler should assure that the sleep hygiene and chronohygiene recommendations in Chapter 2 are met. Part time workers may need more days off for recovery than the full-time shiftworkers due to poor sleep habits forced upon the part-timers by schedule unpredictability.

Section B—Time

Component 3, Shiftwork Type. Fundamentally, there are two solutions that may be applied to the 24/7 scheduling problem: fixed shifts and rotating shifts. With respect to rotating shifts, there are two options: fast and slow rotation.

The Fixed-Shift Solution. On fixed shifts, the worker always works the same shift; for example, permanent days or permanent nights. Most fixed-shift workers tend to become dissatisfied with fixed shifts and wish to "graduate" to day shifts. Besides obvious inequities for workers between fixed day and night shifts, fixed night-shift workers usually do not keep their day-sleep, night-work schedule on days off. Thus, fixed shift schedules assume much of the nature of poorly-scheduled rotating shifts.

Though there are usually some major problems with fixed shifts, there are workers who prefer night work to day work and function quite well at night. If you need only a skeleton crew for night operations and you have a crew of night workers that you trust to operate the system competently, then fixed shifts may be appropriate for your operation. Use these rare workers and be thankful for them: they solve your night shift scheduling problem. Your other workers may be assigned to permanent day shifts, to permanent day and swing shifts or to alternating day and swing shifts. Workers on day and swing shifts usually get adequate nocturnal sleep.

The Rotating-Shift Solution. Many 24/7 operations are supported by rotating shiftwork, in which the worker changes (rotates, as the hands of a clock rotate around the clock face) from one shift to another at some specified interval, be it "fast" or "slow." There are infinite numbers of possible rotating shiftwork plans. The principle-based scheduling approach presented in this Manual should help you constrain the infinite number of possible rotating shiftwork plans to those that are practical to implement and least harmful to shiftworker health, job performance and attitude.

Rotation Direction. One of the controversies that you must deal with in shiftwork scheduling is the decision to use a fast or slow shift rotation. A fast rotation is one in which the workers move to a new shift start time once every few days or less. A slow rotation is one in which they change shifts every few weeks or less often. Weekly changes, used often in the United States, are the least desirable in terms of minimizing physiological disruptions and should be avoided[24]. Unfortunately, direct comparisons of the relative health, safety and productivity effects of rapid vs. slow rotations are rare to non-existent; thus, the scheduler has no firm scientific basis for this part of the decision process. However, there are actions that you may take to help resolve the dilemma. These include:

- Educate workers or worker ombudsmen about chronohygiene and the scheduling Principles and Components
- Examine many possible slow- and fast-rotation options
- Use the nine Principles as a basis for comparisons across shift plans (see Chapter 4)
- Educate workers or worker ombudsmen about the good schedule options for their specific work environment

[24] Office of Technology Assessment, U.S. Congress (1991), *Biological Rhythms: Implications for the Worker*. Committee Report OTA-BA-463, U.S. Government Printing Office, Washington DC.

- Allow the workers to choose one plan from among several good options by a democratic vote

You should also be aware that, compared to faster rotation, slower rotation may provide longer continuous time off. Two examples are given in Table 3, one for 8-h shifts and one for 12-h shifts.

Table 3. Two examples of slower rotation providing longer continuous time off than a faster rotation. D is a day shift, S is a swing shift, N is a night shift, O is a day off.

Shift Plan	Slower Rotation	Faster Rotation
8-h, 3nW:1nF, n = 2	DDSSNNOO	DSNODSNO
12-h, 2nW:2nF, n = 2	DDNNOOOO	DDOONNOO

Generally, rotating shift plans should use forward (clockwise) shift rotation for 8-h shifts. That is, the new shift starts later on the clock than the present shift; for example, rotating from day (D) to swing (S) to night (N). Data from many laboratory studies have shown that the cycle length of the body clock is slightly longer than 24 hours, and is "entrained" to exactly 24 hours by the local day-night cycle. When the 24-hour, day-night cycle cue[25] is removed, in a laboratory setting, then the body clock usually "free runs" at its slightly longer period length. Similarly, when we ignore the day-night cue in shiftwork or when we change it by crossing time zones rapidly to the west, the body clock tends to free run. It is speculated that the longer-than-24-hour body clock period is responsible for the well-documented observations that people deal better with forward shift rotations than backward rotations, and acclimate more quickly to rapid westward time zone changes than to rapid eastward changes.

Backward (counterclockwise) rotation would be S to D to N to S, in which the new shift starts earlier than the present shift. There can be only 8 hours off or there must be at least 32 hours off between these backward rotations. Repeated 8-h rotations will cause a rapid accumulation of sleep debt and fatigue. It some cases, workers are inappropriately charmed by the long 32-hour breaks.

Note that you cannot "rotate" D to S or S to N without time off between shifts. If there is no time off between shifts, then you are not rotating; you are pulling double shifts and working 16 straight hours. Also note that there is no forward-backward difference for 12-h shifts because they are 180 degrees out of phase on the clock. You just alternate between working days and working nights.

Component 4, Shift Length and Overlap. In theory, shift length may be any amount of time up through 24 hours. In practice, only the even factors of 24 hours (2, 4, 6, 8, 12 or 24 hours) are useful. If you use values that are not factors of 24 hours, the time an individual reports for work on the same shift differs from day to day. If you think about working a schedule, or managing people who work a schedule, in which the report time

[25] Also called a *Zeitgeber*, the German word for "time giver."

changes from day to day and night to night, you may imagine much frustration. Trying to determine your next report time through a haze of fatigue can lead to many missed shifts and erroneously-timed arrivals at work.

Shift overlap ("hand off") is not accounted for in this shift length discussion. Shift overlap is the time spent before and after a shift to transition control of the system from the crew ending its shift to the crew starting its shift. Overlap is not used in calculations and comparisons of shiftwork plans because overlap requirements vary only as a function of the work domain, not as functions of the shiftwork Principles or Components. However, overlap must be used for calculations of total numbers of hours worked and pay, after the shiftwork plan has been selected. Often, excessive overlap times are viewed as necessary by management. Unfortunately, these long overlaps extend the workday so much that there is a high risk of cumulative fatigue, followed by chronic fatigue and accompanying morale and retention problems.

The most-debated issue concerning shift length these days concerns the use of 12-h shifts instead of 8-h shifts. (You may also have some interest in shift lengths of 4, 6 and 24 hours. These shift lengths are discussed in Attachment 3.) Shiftworkers are quick to notice that, due to the work compression afforded by 12-h shifts, they can have longer continuous periods of time off when working 12-h shifts than when working 8-h shifts. These longer time-off periods are viewed as being of high value, and so shiftworkers often prefer 12-h shifts to 8-h shifts. However, there is well-placed concern about the use of the 12-h shift length as discussed above, under Principle 2.

There are some differentiating factors for the selection of the 12-h rather than the 8-h shift length: one is continuous operations[26] and another is public risk[27]. Generally, twelve-hour shifts are not appropriate for continuous operations. Though this conclusion is valid in most cases, it may not apply to instances of non-continuous work. For example, military personnel involved in the careful monitoring of displays may work an hour then rest an hour. This intermittent work schedule is designed to allow the maintenance of vigilance throughout a 12-h shift. It requires a slightly higher than expected employment ratio (Component 2), and the number of additional people needed can be calculated by treating the within-shift rotation as a mini-shift plan. Twelve-hour shifts are also not appropriate if shiftworkers have "safety-sensitive" jobs. Safety-sensitive jobs include such things as operating a nuclear power generating station, flying, driving, operating weapons, and making command and control decisions.

The U.S. Congress Office of Technology Assessment paraphrased a Nuclear Regulatory Commission assessment of the potential advantages and disadvantages of 12-h shifts

[26] PM Lewis (1985), *Recommendations for NRC Policy on Shift Scheduling and Overtime at Nuclear Power Plants*. U.S. Nuclear Regulatory Commission, Washington, D.C., NUREG/CR-4248, PNL-5435.
[27] RJ Kelly, MF Schneider (1982), *Journal of Human Ergology* 11, Supplement, 369-384.

compared to 8-h shifts. They are summarized in Table 4[28]. The moonlighting issue cited in that table is a common problem that may lead to unacceptable levels of on-the-job fatigue. Also, the elevated risk of being involved in a fatigue-induced traffic accident is present after a night shift of any length (see Chapter 1, Section C). The decision to use a 12-h shift should never be made lightly. Reduced levels of safety, productivity and worker satisfaction may occur as a result of a change to a relatively long shift length. Some mitigating factors that may support the use of the 12-h shift length include:

- Light physical work
- Intermittent work
- Remote site operations

Some factors that argue against the use of the 12-h shift length include:

- Heavy physical work
- Demanding, repetitive mental work
- Safety sensitive work
- Public safety
- Work requiring sustained alertness (vigilance)

[28] U.S. Congress Office of Technology Assessment (1991), *Biological Rhythms: Implications for the Worker;* Committee Report OTA-BA-463, Washington DC: U.S. Government Printing Office.

Table 4. The potential advantages and disadvantages of 12-h shifts compared to 8-h shifts (from the Nuclear Regulatory Commission, paraphrased by the Office of Technology Assessment).

ADVANTAGES	DISADVANTAGES
Because most workers like 12-h shifts:	**Because 12 h of work per day is more fatiguing than 8 h:**
• Increased job satisfaction and morale	• Alertness and safety may decline
• Increased job satisfaction and decreased attrition; fewer recruiting difficulties	• Workers may work at a slower pace
• Reduced absenteeism due to proportionate loss of pay	• Workers need more breaks
• Sleep time more easily adjusted for two than for three shifts	• 12-h night shifts are more difficult than 8-h night shifts
	• 12-h shifts may be difficult for older workers
Because of more days off and more consecutive days off:	**Because of more days off and more consecutive days off:**
• More family and leisure time	• Workers lose touch with operations
• Less personal time taken from work	• While off, workers may engage in moonlighting, long-distance travel, or exhausting recreation, and return to work fatigued
• Fewer consecutive workdays and more rest days to dissipate fatigue [the chronic fatigue problem]	
Because of fewer shift changes per day:	
• Reduced number of communication errors	
• Improved continuity of operations	
• More likely that the crew that starts an operation will finish it, contributing to quality work and job satisfaction	
• Reduction of commute time and cost	

Section C—Basic Structure

Component 5, The Shift System. The specification of the shift system (1) is the "lowest common denominator" that allows direct comparisons across shiftwork schedules, and (2) reveals the ratio of the nominal number of days to be worked to the nominal number of free days. In addition, (3) the sum of the two nominal integers in the system usually reveals the number of crews that must be used to support the system, and (4) the sum of the products of the nominal integers and their multipliers reveals the cycle length of the

system. Shiftwork researchers[29] have examined 4-crew shift systems in great detail with respect to two constraints: 8-h work days and 104 days off per year (equal to 52 weekends per year). They showed that the 40-hour work week is cumbersome and limiting when you try to create a shiftwork plan, and that the 42-hour work week allows even distributions of work time across workers on all shifts. The latter is true because the week length, 168 hours, is factorable by 42 hours (4 x 42 hours = 168 hours). Just this one piece of information, that the week divides nicely into four 42-hour segments, suggests that the 42-hour work week may make wonderful sense for shift scheduling.

Having established that the 4-crew solution with a 42-hour work-week worked quite well, the researchers went on to determine the best ratios of work days and free days:

- For 8-h shifts, use a ratio of 3 work days to 1 free day (3:1)
- For 12-h shifts, use a ratio of 2 work days to 2 free days (2:2)

Incidentally, this shift system examination also provided us with two of the useful measures for determining the acceptability of a shift system: the average number of hours worked per day and the number of free days per year. Note that, unlike strictly mathematical ratios, the shift plan notation may not always be fully reduced. For example, the recommended 2:2 ratio, above, was purposefully not reduced to 1:1.

The shift system sets the relative numbers of work and free periods that must be worked to support 24/7 operations. A system is expressed as the ratio,

$$XnW:YmF$$

where X and Y are integers (the numbers 1, 2, 3, etc.), m and n are multipliers (also integers), W represents work days, and F represents free days (days off). In practice, n and m are almost always the same number, so we will express the ratio as XnW:YnF. The *cycle length* of a shift system is the sum of Xn + Yn.

Thus,

- The ratio of 3 work days to 1 free day (3:1) for 8-h shifts is expressed as the system, 3nW:1nF
- The ratio of 2 work days to 2 free days (2:2) for 12-h shifts is expressed as the system, 2nW:2nF

where n is an integer multiplier. These are optimal systems for shiftwork scheduling. Thus, they are a good place to start when building a schedule from scratch.

The converse operation to building a schedule from scratch is the analysis of an existing schedule to fully understand its structure and its compliance with the intentions of the Principles, above. To do this, start by laying out one full cycle of the existing schedule

[29] P Knauth, J Rutenfranz (1976), *International Archives of Occupational and Environmental Health*, v. 37, pp. 125-137. Also, P Knauth *et al.* (1979), *Applied Ergonomics*, v. 10, pp. 9-15.

and carefully identifying and counting both the W and the F days. Caution: some W days may be identified as such incorrectly because (1) work occurs on that day, but the shift starts on the day prior, or (2) non-shiftwork occurs on that day. Write down the ratio of W to F for shiftwork. For example, for the sequence WWWWWWOO, the ratio is 6W:2O. Now, remove the common denominator. In this case, the schedule reduces to 3nW:1nF with n = 2. This tells us that the cycle length is, in fact, (6 + 2 =) 8 days and that the system probably requires (3 + 1 =) 4 crews. Subsequent methods for schedule assessment are presented in Chapter 5.

Component 6, The Shift Plan (Shift *Rota*). The shift plan determines the sequence of work (W) and free (F) days within a shift system. The notation is D, S, and N for the W "days" (day, swing and night shifts, respectively) and O (off) for F or rest "days" (basically O and F are the same thing). The daily notation refers to the start of a shift. If a shift starts at 2300h, then this is a W day even though only one hour is worked. The day after this shift is an F day if no shift starts this day, though many hours are worked from midnight on. There is a lesson here: be sure to examine proposed F days carefully for their quality of time off.

One shift system may allow many shift plans. For example, the 12-h, 2nW/2nF system with n = 1 allows twelve different plans in three serially-identical sets (Table 5). For example, when it starts repeating, DONO has the same sequence as NODO in Set 1. Set 2 is the preferred sequence because days off (O) follow night work (N) and there are two consecutive days off. Set 3 would require double-shifting (from N to D on the same morning).

Table 5. The twelve different shift plans available in the 12-h, 2W/2F shift system form three serially-identical sets. D = day shift, N = night shift, O = day off.

Set 1	Set 2	Set 3
DONO	DNOO	DOON
NODO	NOOD	NDOO
ODON	ODNO	ONDO
ONOD	OODN	OOND

The Continental *rota*, or 2-2-3 plan, is a plan in the 3nW:1nF shift system with n = 7 and a cycle length of 28 days. It includes three sequences each of two, two, and three consecutive days off (O), day shifts (D), swing shifts (S) and night shifts (N). The 3-day sequences are underlined here:

DDSSNNNOO DDSSSNNOO DDDSSNNOOO

There are two weaknesses in this plan: the three consecutive night shifts and the seven consecutive work days. The Metropolitan *rota*, or 2-2-2 plan, is one of many alternatives to the Continental *rota*, and is a slight improvement in the areas of these two weaknesses. The Metropolitan *rota* is another plan in the 3nW:1nF system (n = 2), with 6 sequential work days and 2 sequential night shifts in an 8-day cycle:

DDSSNNOO

With respect to the concept of work compression, the highest numbers of consecutive days off within a plan are reached when all occurrences of the same shift are consecutive or when all work days are consecutive. An example was given in Table 3 with the fast-slow rotation discussion under Component 3, Shiftwork Type.

Section D—Interactions

Component 7, Shift differentials. Shift differentials are usually hourly pay rates that differ between, for example, day and night shifts. Differentials may also be provided by keeping pay constant and adjusting the number of hours worked. The results of a Federal Aviation Administration investigation of stress in air traffic controllers suggested that the day shift is more stressful than the swing or night shifts[30]. This may be due to the presence of administrative personnel during the day shift and to higher task work loads during the day shift. However, we know that the night shift is physiologically stressful, too[31]. Thus, it may be advisable to use differential shift lengths of 8-h days, 9-hour swings, and 7-hour nights (8D-9S-7N) or 8D-10S-6N or 9D-9S-6N. This may allow the worker to deal more appropriately with the relative stresses of the shift periods. At least one hospital has used this approach with success[32].

A differential shift length shortens the amount of time off between shifts for one shift and lengthens it equally for another. For example, if the shift change times for an 8D-9S-7N schedule are 0700, 1500, and 0000, the day worker will be off 16 hours (from 1500 to 0700), the swing shiftworker will be off 15 hours (from midnight to 1500), and the nightshift worker will be off 17 hours (from 0700 to midnight). However, this free-time difference will affect all workers equally across each rotation cycle. Note, also, that the use of a shift length differential with equal assignments does not affect the average workday length.

Component 8, Alignment with Weekends. The alignment of the shift plan with the calendar week helps to implement Principle 5, concerning the number of free weekend days. Shiftwork researchers[33] have noted that the 3nW:1nF, n = 7 (21W:7F) system for 8-h shift lengths, and the 2nW:2nF, n = 1 (2W:2F) system for 12-h shift lengths are useful for alignment. They both allow cycle lengths of four weeks, and one free weekend per 28-day month. You saw in the discussion of Principle 5 that the slowly-rotating

[30] CE Melton *et al.* (1973), *Physiological, Biochemical, and Psychological Responses in Air Traffic Control Personnel; Comparison of the 5-day and 2-2-1 Shift Rotation Patterns*. Federal Aviation Administration, Office of Aviation Medicine, Washington, D.C., FAA-AM-73-22.
[31] J Ilmarinen *et al.* (1975), *International Journal of Chronobiology*, v. 3, pp. 3-4. Also, J Wojtczak-Jaroszowa, A Banaszkiewiez (1974), *Ergonomics*, v. 17, pp. 193-198.
[32] J Puhek (1984), *AARTIMES*, v. 8, pp. 40-44.
[33] P Knauth and coworkers, *op. cit.*

Panama plan for 12-h shifts with 1nW:1nF, n = 7 (7W:7F) allowed every other weekend off. This is another example of a slower rotation providing longer periods of continuous time off. Note also that a 2-week or 4-week cycle length allows equal distributions of all shifts and free days throughout the year since the year is divisible into thirteen 4-week months.

The researchers also showed a tabular method to examine the yearly distribution of shifts across days of the week. For example, the 28 days of the Continental *rota* (21W:7F), arranged by weeks in one of the possible phase relationships with the days of the week, looks like Table 6. The three right-hand columns of Table 6 (Fri-Sat-Sun) reveal the types of weekends created by the selected shift alignment. Summing the 13 4-week periods in the year gives yearly distributions of weekend types; in this case, 13 each of four types. Table 7 shows an alignment for 56 days on the DDNNROOO (2nW:2nF, n = 2) plan discussed under Principle 5, and Table 7 shows the every-other-weekend-off alignment for the Panama plan also discussed under Principle 5.

Table 6. Shift alignment table for the 28-day cycle of the Continental *rota*. Read from left to right, and then drop to the next line to continue reading. D is a day shift, S is a swing shift, N is a night shift, R is a recovery day, O is a day off.

	Day						
Week	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**
1	D	D	S	S	N	N	N
2	R	O	D	D	S	S	S
3	N	N	R	O	D	D	D
4	S	S	N	N	R	O	O

Table 7. Shift alignment table for 56 days of the 8-day DDNNROOO plan.

	Day						
Week	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**
1	D	D	N	N	R	O	O
2	O	D	D	N	N	R	O
3	O	O	D	D	N	N	R
4	O	O	O	D	D	N	N
5	R	O	O	O	D	D	N
6	N	R	O	O	O	D	D
7	N	N	R	O	O	O	D
8	D	N	N	R	O	O	O

Table 8. Shift alignment table for the 14-day cycle of the Panama plan. W is a work day (12-h day or night shift with rotation once every 28 days); O is a day off; R is a recovery day if W is the night shift, else it is a day off (O).

	Day						
Week	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**
1	W	W	R	O	W	W	W
2	R	O	W	W	R	O	O

Component 9, Shift Change Times. The selection of the morning shift change time depends upon both physiological and social factors. Most normally-aligned circadian rhythms in human physiological function and performance are expected to reach their lowest point (nadir) during the early morning hours preceding dawn[34]. This is the peak time for errors and injuries in continuous operations (adjusted for exposure). To minimize sleep disruption and fatigue in workers, sleep should occur during the hours of darkness. Note that a 3-shift schedule will disrupt only the sleep of the night shift; day and swing shift workers can sleep well at night.

You may deal with the pre-dawn nadir in one of three ways. First, place the shift change after dawn. This selection maximizes the quality of rest for the day shift. Second, place the shift change during the performance nadir, for example, one hour before dawn. This selection has the advantage of alerting the night workers during the performance nadir, since they know they are about to go home. It has the disadvantage of disrupting sleep for the day workers.

Third, place the shift change before the nadir. You might see this selection as having the advantage of bringing rested "day" workers in to deal with the performance nadir. However, their sleep will be extremely disrupted and one will have two shifts of workers, day and night, with disrupted sleep, rather than just the night shift workers.

You should also consider social factors, particularly family schedules and local automobile traffic. A worker on the "day" shift who must arise between midnight and dawn may disrupt family sleep patterns, leading to family discord and worker fatigue. You should consider nominal worker and family sleep periods in planning the shift change time. You may also wish to minimize the interactions of shiftworker vehicle traffic with local rush hours.

A shift change at 0700 is often effective. Day (0700 to 1500) and swing (1500 to 2300) shiftworkers can get normal nocturnal sleep, family sleep is not disrupted by early-rising day workers, and the day and night workers commute to and from work before the usual 0800 rush hour. However, you must keep night workers (2300 to 0700) alert during the

[34] Recent studies of military pilots flying simulators, by Dr. John Caldwell of the Air Force Research Laboratory, have suggested that the nadir in flying performance (manual handling of the aircraft) may occur well after dawn following all-night work. This finding may be applicable to workers pulling a double shift of night, then day.

pre-dawn performance nadir. There are various techniques available, including increased physical activity, bright light, and "signal injection" for boring, repetitive tasks with strong quality control demands. Guidance from the National Sleep Foundation is provided in Table 9.

Table 9. Tips for promoting alertness at work, from the National Sleep Foundation.

PROMOTING ALERTNESS AT WORK
Take short breaks throughout the shift
Try to work with a "buddy"
Talking with co-workers can help keep you alert; and co-workers can be on the lookout for signs of drowsiness in each other
Try to exercise during breaks; use the employee lounge, take a walk, shoot hoops in the parking lot, or climb stairs
Try to eat three normal meals per day; eat healthy snacks, avoiding foods that may upset your stomach
If you consume caffeine (coffee, tea, soda, energy drinks, gum, mints), do so early in the shift, e.g., before 3 a.m. for the night worker
Don't leave the most tedious or boring tasks to the end of your shift when you are apt to feel the drowsiest
Exchange ideas with your colleagues on ways to cope with the problems of shiftwork; set up a support group at work so that you can support and learn from each other
If you operate heavy equipment, drive a vehicle during your shift, or provide health care, you must pay careful attention to signs of sleepiness or fatigue. To ignore signals such as yawning, frequent blinking, a sense of tiredness and a failure to make routine safety checks may put you and others at risk. If you feel sleepy or drowsy, stop your work as soon as safely possible. Contact your supervisor and request a break or nap, or have a caffeinated product in order to help increase alertness. Remember, caffeine is not a long-term substitute for sleep.
FOR THE EMPLOYER
Educate managers and shiftworkers about the need for sleep and the dangers of fatigue
Install bright lights in the work areas; a well-lit workplace signals the body that it is time to be awake and alert.
Provide vending machines with healthy food choices
Schedule shifts to allow sufficient breaks and days off, especially when workers are re-assigned to different shifts
Plan enough time between shifts to allow employees to both get enough sleep and also attend to their personal life
Don't promote overtime among shiftworkers
Develop a napping policy. Encourage napping by providing a sleep-friendly space and time for scheduled employee naps. A short break for sleep can improve alertness, judgment, safety, and productivity.
Be concerned about employee safety going to and from work. Encourage the use of carpools, public transportation, rested drivers, and even taxis.

Chapter 4

SCHEDULING METHODS AND EXAMPLES

Section A—Steps and Tools

Consider writing a unit operating procedure concerning the scheduling of 24/7 ops. Here is a recommended approach:

> Shift length. The nominal shift length is limited to a maximum of 8 hours. A nominal shift length of 12 hours may be allowed on the basis of a written operational risk management plan for dealing with elevated, fatigue-induced risks associated with the longer shift length.
>
> Staffing level. The unit staffing level shall provide at least four crews for each 24/7 operation (or at least four people for each 24/7 position), plus enough staff overage for that operation (or that position) to deal with pre-calculated amounts of sick time, vacation, holidays, and training. Five-crew (or more crews) operations that are 4-crew, 24/7 operations plus 5-day weeks of normal duty days (daytime work only) are allowed.
>
> For 8-h shifts and 4 crews in 24/7 operations, each individual shall be scheduled at a ratio of three work days to one free day, for no more than six sequential work days before one free day of at least 24 hours, for no more than nominal 84 hours of work in 14 days, and for no more than 168 nominal hours of work in 28 days.
>
> For 12-h shifts and 4 crews in 24/7 operations, each individual shall be scheduled at a ratio of one work day to one free day, for no more than four sequential work days before one free day of at least 24 hours, for no more than 84 nominal hours of work in 14 days, and for no more than 168 nominal hours of work in 28 days.
>
> Provide written, specific limits for shift overlap (or turn-over), training, administrative time, and overtime, beyond the nominal limits, above.

The use of these nominal limits will force the design of a simple, predictable, equitable shiftwork schedule. The following steps will aid you in the design process within these or similar constraints.

First, determine how many employees you have available for shiftwork. To do this, do <u>not</u> count non-shiftworkers who can fill in for shiftworkers who are sick or on vacation or in training, and do <u>not</u> yet apply an employment ratio.

Second, examine the distribution of the shiftworker coverage you need as a function of the calendar and clock. Fill in the number of people you <u>need</u> at work in each blank of a Work Demand Table (Table 10). You may wish to fill in copies of the Table for different work areas at your site. Consider only the work <u>demand</u> here, <u>not</u> the number of people you have

available. Pay particular attention to the possibility of using a reduced number of people during large blocks of time, such as evenings, nights, and weekends. This exercise may pinpoint sharply-differing work demands within your operation. These differences may require complex approaches to shift scheduling. For example, one area of the operation may demand full crews around the clock, seven days a week, while another demand may be satisfied with nighttime or weekend skeleton crews.

If you find that you have low demand on weekends, then the "Australian" combined shift system may be useful for you. If you find that you have low demand at night, then the "Canadian" split crew system may be useful.. These complex schedules are shown in Section G. If the work demand is approximately equal across all days and hours, then a standard plan (no combined shifts or split crews) would be your logical choice. In addition to helping with decisions about shiftwork scheduling, the Work Demand Table may also help reveal periods when one member of a crew at a time could leave work without weakening the crew's work quality.

Third, decide what shift length you will be using. Fourth, decide how many crews you will use. There is a best mathematical solution: four crews for both 8- and 12-hour shift lengths. The 4-crew selection gives the average 42-hour work week.

At this point, you have decided upon the number of crews and you know the number of people per crew (from the work demand table, Table 10). Recall that the most prevalent cause of shiftwork schedule problems may be management's failure to calculate the employment ratio and then to assure the availability of enough qualified shiftworkers to meet the 24/7 work demand.

Thus, fifth, compare the number of available workers to the work demand. Consult your organization's policy documents to determine the numbers of holidays and leave days allowed for each worker. Estimate the number of days of training needed by each worker. Now calculate your employment ratio and the number of people you will need to staff your shiftwork system (see Component 2).

Either you will or will not have enough people. If you do not have enough, there are two paths that may be taken. The most desirable path is to hire more people so that you can staff the shiftwork system that works best for your operation. The least desirable path is to use fewer crews. This path may be one of false economy. That is, while the up-front costs of hiring more people and the continuing costs of paying them will be saved, the savings may be lost because of fatigue-induced errors on the job and reduced morale that leads to high employment turnover. Another path is to use fewer people per crew, if the work demand allows this approach. Conversely, if you do have enough people, but have a very high training demand, you may wish to consider a 5-crew plan. If so, then see Section E.

Sixth, decide whether you will use a slow or fast (not weekly) rotation plan or fixed shifts. This is where you pick your combination of shift system (the ratio of W to F) and shift plan (the sequence of W's and F's). Your decision about speed (or lack) of rotation may be influenced and delayed by the politics of current practices, biases (perhaps without

substance) among workers and management, labor contracts and negotiations, and so forth. However, the decision will have to be made before you can continue to design the shiftwork schedule.

The fastest rotation for 8-hour shifts and four crews would always be available in the 3nW:1nF system with n = 1. The plan would use the sequence, DSNO. However, this system provides only an inadequate one day off per cycle. A slow rotation for 8-hour shifts and four crews would be available in the 3nW:1nF, n = 28 (84W:28F) system. An employee could work 28 consecutive day shifts, then 28 consecutive swings, then 28 consecutive nights, then have 28 consecutive days off; or the days off could be mixed in among the various shifts. This approach will probably call for too many sequential work periods, too many sequential nights of work and inadequate rest after night shifts. However, it may be preferred for social reasons in some situations.

The fastest rotation for 12-hour shifts and four crews would always be available in the 1nW:1nF system with n = 2 or the 2nW:2nF system with n = 1 (both systems result in the plan, DNOO).

A slow rotation for 12-hour shifts and four crews would be available in the Panama plan (1nW:1nF with n = 7, rotating once every 28 days). A similar schedule could be arranged in the 2nW:2nF, n = 28 (56W:56F) system. An employee could work 28 consecutive day shifts, 28 consecutive nights, and have 56 consecutive days off.

Note the emphasis on factors and multiples of 28-day cycles in these minima and maxima. The use of the 28-day cycle keeps assignments and free weekends equal for all employees across the 364-day year.

Table 10. Work Demand Table. Enter the number of people you need to have working in each hour for each day of the week.

Hour	Mon	Tue	Wed	Thu	Fri	Sat	Sun
00							
01							
02							
03							
04							
05							
06							
07							
08							
09							
10							
11							
12 Noon							
13 (1)							
14 (2)							
15 (3)							
16 (4)							
17 (5)							
18 (6)							
19 (7)							
20 (8)							
21 (9)							
22 (10)							
23 (11)							

Now, a good method for summarizing your plan for all crews is the Shift Plan Table (Table 11). There are 28 sequential days running down the left side of the table. Five columns of the table provide space for up to up to five crews, called Crew A, Crew B, *etc.* A checkmark placed at the right of the table, allows you to make sure each shift is filled each day. If you are going to use a cycle length (one cycle = all W + all F days) greater than 28 days to create a slow shift rotation, use copies of this page and place them end to end.

In the Crew A column, pencil in your shift plan from the top down using the symbols D, S, N, R and O for day shifts, swing shifts, night shifts, recovery days and days off, respectively. Use just the symbols D, N, R and O for a 12-hour shift-length plan. If you are using a fast rotation, pencil in the plan several times in the 28 days of the table, starting a new cycle below the cycle above.

Next, find the number of lag days at which to start penciling in the same plan for Crew B. The number of lag days is usually the value of F from your shift system, or one-half of F. It may also be all or half the total of W and F. Count down the expected number of lag days from the start of Crew A's plan, and, starting at that point, pencil in the same plan for Crew B in the Crew B column, to the right of the Crew A column. Pencil in the same plan for Crews C, D, *etc.*, using the same number of lag days from the crew to the left, and using the same plan. From the bottom of each column, wrap around to the top of that column and continue penciling in the schedule.

Finally, scan across each day. If you are using 12-h shifts, look for one and only one D in each day's line, one and only one N in each day's line. If the column meets these criteria, place a check mark for that day in the summary column at the right for that day. If you are using 8-h shifts, look for one and only one D, one and only one S, and one and only one N in each line. If the column meets these criteria, place a check mark for that day in the summary column at the right for that day.

If all days meet the criterion, then each shift is filled by one crew on every day of the cycle. This is what you want. If some lines do <u>not</u> meet this criterion (some check marks are missing), go back and try another number of lag days. Make sure you are using the <u>same plan</u> in every crew column. If, after trying all lag lengths from one up to the total of the W and F in your system, you cannot fill each shift with one crew each day, you need to re-examine your decisions about numbers of crews and numbers of shifts per day.

A non-table way to find the number of lag days is to type out the plan several times, print it out, cut it into strips, and move the strips back and forth next to each other until you have only one crew per shift per day. Your typing might look like this for four cycles of the 4-crew, 12-h, DDNNROOO plan:

Crew A: D D N N R O O O D D N N R O O O D D N N R O O O D D N N R O O O

Crew B: D D N N R O O O D D N N R O O O D D N N R O O O D D N N R O O O

Crew C: D D N N R O O O D D N N R O O O D D N N R O O O D D N N R O O O

Crew D: D D N N R O O O D D N N R O O O D D N N R O O O D D N N R O O O

Table 11. Shift Plan Table. Insert a shift symbol on each day for each crew: D for day shift, S for swing shift, N for night shift, R for recovery day, O for day off. Place an X in the right hand column when each work shift is covered by one and only one crew each day. See Chapter 6 for examples.

Day	A	B	C	D	E	X
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						

To help determine whether your shift plan provides good quality time off on weekends, enter your plan in a Shift Alignment Table (Table 12). The table allows for a plan with a cycle length up to 91 days (13 weeks). Use only as many lines of the Table as required by the cycle length (one cycle = all W + all F days) of your plan. Start on the top line (Week 1), under the day of the week on which you wish your plan to start for Crew A. Continue entering your plan from left to right, and then top to bottom. Stop when you reach the end of one cycle. If you find that you have created no, or not enough, weekends on which the crew is free, re-start the plan on a different day of the week.

Table 12. Shift Alignment Table. Start on the top line (Week 1), under the day of the week on which you wish your plan to start for Crew A. Continue entering your plan from left to right, and then top to bottom. Stop when you reach the end of one cycle. See Chapter 6 for examples.

Week	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							

Section B—4-Crew Solutions

You have seen that the 4-crew solution is optimal for routine, non-maritime shiftwork operations, and have read of several 4-crew solutions in the earlier chapters. These solutions generally sort into four groups: 8-h shifts with fast and slow rotations and 12-h shifts with fast and slow rotations. Examples are shown in Table 13. Side-by-side descriptions of these plans are shown in Table 14.

Table 13. Examples of the four basic 4-crew solutions.

Shift Length	Fast Rotation	Slow rotation
8-h shifts	Continental *rota* Metropolitan *rota*	84W:28F, with 6W followed by 2O
12-h shifts	DDNNROOO	Panama plan

Table 14. Side-by-side descriptions of some basic 4-crew solutions.

	Plan	Sequence
Fast	Continental *rota* 8-h shifts, 28-day cycle	DDSSNNNOO DDSSSNNOO DDDSSNNOOO
	Metropolitan *rota* 8-h shifts, 8-day cycle	DDSSNNOO
	Fast 12-hour plan 12-h shifts, 8-day cycle	DDNNROOO
Slow	84W:28F 8-h shifts, 112-day cycle Work 6 D or N, then 2 O	WWWWWWOOWWWWWWOO…
	Panama plan 12-h shifts, 14 day cycle Rotate D-N after 28 days	WWOOWWWOOWWOOO

These 4-crew plans may be compared with respect to how well they comply with the intents of the scheduling Principles. Sample comparisons are shown in Table 15. Because Type 3 plans always contain night work, and night work almost always disrupts the circadian rhythm, Principle 1 (circadian stability) provides no differentiation between the plans here. Instead, the relevant circadian criterion within Type 3 systems is the number of consecutive nights that must be worked: three is acceptable here, and four is not. The converse of Principle 6 and an extension of Principle 3 are added here for comparison purposes: **Principle 3a, Few Consecutive Work Days** (W). Five consecutive W days is acceptable (as experienced by weekday-only workers); six consecutive W days is not. Since all of these plans are equitable and predictable, Principles 7 and 8 provide no differentiation between plans here. Because the 8-h shift plans rotate clockwise, Principle 4 provides no differentiation, either.

For the comparison of 8-h shifts to 12-h shifts, the work compression effect of the 12-h shift provides various gains in Principles 3, 3a, 5, 6, and 9. There is no obvious advantage for either slow rotation or fast rotation in the comparisons in Table 15. Of the five plans, the Panama plan appears to be the best overall for achieving the aims of the

Principles. However, all shiftwork schedules have weaknesses because they call for night work. The weakness of the Panama plan is one that should cause great concern: it calls for the use of 12-h shifts. If the 12-h shift is unacceptable, then there are several 8-h shift plans from which to choose. Among the 8-h plans, the Continental *rota* is best for achieving the aims of the Principles, but it is weak in terms of Principles 3a (consecutive W) and 5 (F per year). To select one plan from among several possibilities, managers and employees must consider the relative strengths and weaknesses of various plans with respect to the inherent demands and risks of their specific work domain.

Table 15. Sample comparisons of 4-crew plans with respect to the scheduling Principles. The comparisons for Principle 5 are standardized to a 2-month (56-day) period. "Yes" answers for the other Principles indicate compliance with the intent of the Principles.

Fast Rotation Plans:	**Continental**	**Metropolitan**	**Fast 12-hour**
P1. Circadian entrainment	No	No	No
P2. Shift ≤ 8 hours	Yes	Yes	No
P3. Few consecutive N	Yes	Yes	Yes
P3a. Few consecutive W	No	No	Yes
P4. O after N	Yes	Yes	Yes
P5. Max F on weekends	2 wkend per 2 mo	1 wkend + 2 d per 2 mo	2 wkend + 2 d per 2 mo
P6. ≥ 104 F/yr	No (91 F)	No (91 F)	Yes (182 F)
P7. Equity	Yes	Yes	Yes
P8. Predictability	Yes	Yes	Yes
P9. Good quality time off	Yes (3 d)	No	Yes (4 d)

Slow Rotation Plans:	**84W:28F (6W & 2O)**	**Panama**
P1. Circadian entrainment	No	No
P2. Shift ≤ 8 hours	Yes	No
P3. Few consecutive N	No	Yes
P3a. Few consecutive W	No	Yes
P4. O after N	Yes	Yes
P5. Max F on weekends	1 wkend + 2 d per 2 mo	4 wkend per 2 mo
P6. ≥ 104 F/yr	No (91 F)	Yes (182 F)
P7. Equity	Yes	Yes
P8. Predictability	Yes	Yes
P9. Good quality time off	No	Yes

Section C—3-Crew Solutions

Land-based operations may be faced with the problem of covering a 24/7 operation with three crews. The discussion in Attachment 3 introduces several 3-crew solutions, based upon the use of 4- and 6-h watch (shift) lengths in the maritime environment. These include the fixed classic maritime watch; the fixed Close 4 watch; and the rotating Close

6 watch[35]. Though applied mainly in the maritime environment, these plans may also be applied to land-based operations. One may also use fixed 8-h or rotating 12-h shifts with three crews. For the purposes of our comparisons across days and weeks, the classic maritime, the Close 4 and the fixed-8 watches are essentially the same: they all require 8 h of work per day on fixed shifts ("All Fixed 8"). Obviously, they differ greatly among themselves with respect to the adequacy of sleep obtained within each 24-h period, and those differences must also be taken into account by the scheduler in addition to the comparisons made here. Side-by-side descriptions of the plans are shown in Table 16. Sample comparisons of the 3-crew plans are shown in Table 17. All of the fixed-8 solutions suffer primarily from problems with equity and consecutive work days. The equity problems occur because permanent night workers do not have an equitable schedule when compared to permanent day workers. The Close-6 plan fares best in this comparison. It may be most useful for personnel in organizations that live and work within the same facility. Note that another, more complex 3-crew solution is shown in Section G.

Table 16. Side-by-side descriptions of some 3-crew plans.

	Plan	**Sequence**
All Fixed 8	Classic Maritime 4-and-8	WWWWWW...
	Close 4 Submarine By Kleitman	WWWWWW...
	Fixed 8	WWWWWW...
Rotating	Close 6	WWOWWO...
	12-Hour DNO	WWOWWO...

Table 17. Sample comparisons of some 3-crew plans.

3-Crew Plan:	**All Fixed 8**	**Close 6**	**12-Hour**
P1. Circadian entrainment	No	Yes	No
P2. Shift ≤ 8 hours	Yes	Yes	No
P3. Few consecutive N	No	Yes	Yes
P3a. Few consecutive W	No	Yes	Yes
P4. O after N	No	Yes*	Yes
P5. Max F on weekends	No	2 days per 3 wks	2 days per 3 wks
P6. ≥ 104 F/yr	No	Yes	Yes
P7. Equity	No	Yes	Yes
P8. Predictability	Yes	Yes	Yes
P9. Good quality time off	No	No	No

*Work 0000-0600 night 1, sleep 0000-0600 nights 2 & 3

[35] The Close-6 watch is a 72-h cycle that calls for the sequence, 6 h on, 6 h off, 6 h on, 12 h off, 6 h on, 6 h off, 6 on, and 24 h off. JC Miller, J Dyche, R Cardenas, W Carr (2003). *Effects of Three Watchstanding Schedules on Submariner Physiology, Performance and Mood.* Technical Report 1226, Naval Submarine Medical Research Laboratory, Groton, CT.

Section D—2-Crew Solutions

Often, military vessels must put to sea with only two qualified watchstanders for a given position. Usually, a third watchstander is to be trained while underway. Before the third watchstander is trained, the two qualified watchstanders must cover the position 12 h per day, every day. They may choose to do this with 6-h or 12-h shifts or an inequitable combination of shifts. Similarly, land-based operations may be faced with the problem of covering a 24/7 operation with two crews. Because the individuals working from midnight to dawn are highly unlikely to acclimate fully to night work, this plan will usually function adequately for only about three days to a week or two, depending upon the individual night workers. Eventually, fatigue-induced errors and involuntary sleeping on the job impair system performance unacceptably. A comparison of the 6- and 12-h shift options for two crews is shown in Table 18. Neither option is good. Two-crew solutions to the 24/7 work demand problem are to be avoided whenever possible. They are a "stupid" solution to a 24/7 work demand, as defined in Chapter 1.

Table 18. Sample comparisons of two 2-crew plans.

2-Crew Plan:	6-h Shifts	12-h Shifts
P1. Circadian entrainment*	No	No
P2. Shift ≤ 8 hours	Yes	No
P3. Few consecutive N*	No	No
P3a. Few consecutive W	No	No
P4. O after N*	No	No
P5. Max F on weekends	No	No
P6. ≥ 104 F/yr	No	No
P7. Equity	No	No
P8. Predictability	Yes	Yes
P9. Good quality time off	No	No

*For the night workers

Section E—5-Crew Solutions

When there are enough people in the workplace to support five crews and there is a very high training or other non-shiftwork demand, consider using a 5-crew solution. The 5-crew solution that is used to meet training or other non-shiftwork demands is simply a 4-crew solution plus (1) one more crew, and (2) one or more interpolated weeks of normal office hours at a ratio of one office week for every four shiftwork weeks. For example, you can convert the Panama plan into a 5-crew solution. There are four possible 14-day sequences in the Panama. They are listed and labeled here, along with a 14-day sequence of weekday-only work:

- Day1: DDOODDDOODDOOO
- Night1: NNOONNNOONNOOO
- Day2: OODDOOODDOODDD
- Night2: OONNOOONNOONNN
- Office: 88888008888800, where 8 represents an 8-hour workday in the office.

One 40-week cycle of this 5-crew, Panama-plus-office schedule is shown in Table 19. Each crew sees four 10-week repetitions of 8 weeks of shiftwork followed by 2 weeks of weekdays only. In each of the four 10-week repetitions, the crew sees one of the four possible 14-day Panama sequences four times, plus the single 14-day sojourn in the office. Compliance with the scheduling Principles is shown in Table 20, with no differences from the same assessment under the 4-crew solutions heading, above. Again, the main concern should be the use of 12-h shifts. Note that the 40-week cycle means that complete equity will not occur across crews in a 52-week year. In this case, the equity year may be defined as 40 weeks or as a multiple of 40 weeks, as needed.

Table 19. One 40-week cycle of a 5-crew schedule created from the Panama plan. The sequence labels (Day1, Night1, etc.) are defined in the text.

Weeks	A	B	C	D	E
1-2	Day1	Night1	Day2	Night2	Office
3-4	Office	Night1	Day2	Night2	Day1
5-6	Night1	Office	Day2	Night2	Day1
7-8	Night1	Day2	Office	Night2	Day1
9-10	Night1	Day2	Night2	Office	Day1
11-12	Night1	Day2	Night2	Day1	Office
13-14	Office	Day2	Night2	Day1	Night1
15-16	Day2	Office	Night2	Day1	Night1
17-18	Day2	Night2	Office	Day1	Night1
19-20	Day2	Night2	Day1	Office	Night1
21-22	Day2	Night2	Day1	Night1	Office
23-24	Office	Night2	Day1	Night1	Day2
25-26	Night2	Office	Day1	Night1	Day2
27-28	Night2	Day1	Office	Night1	Day2
29-30	Night2	Day1	Night1	Office	Day2
31-32	Night2	Day1	Night1	Day2	Office
33-34	Office	Day1	Night1	Day2	Night2
35-36	Day1	Office	Night1	Day2	Night2
37-38	Day1	Night1	Office	Day2	Night2
39-40	Day1	Night1	Day2	Office	Night2

Table 20. A Principle-based assessment of the 5-crew Panama plan.

Plan:	5-crew Panama
P1. Circadian entrainment*	No
P2. Shift ≤ 8 hours	No
P3. Few consecutive N*	Yes
P3a. Few consecutive W	Yes
P4. O after N*	Yes
P5. Max F on weekends	4 wkend per 2 mo
P6. ≥ 104 F/yr	Yes (182 F)
P7. Equity	Yes
P8. Predictability	Yes
P9. Good quality time off	Yes

*When on the night shift.

Section F—1-Crew Solutions

Occasionally, we are faced with the need for a single individual or crew to execute a 24/7 mission. In 1927, Charles Lindbergh faced this challenge for about 1½ days (33h 30min) during his transatlantic flight. He reported, "My mind clicks on and off. I try letting one eyelid close at a time while I prop the other with my will. But the effect is too much, sleep is winning, my whole body argues dully that nothing, nothing life can attain is quite so desirable as sleep. My mind is losing resolution and control."[36] Unfortunately, Lindbergh carried a significant sleep debt into that flight, and that is one of the lessons that should be applied to 1-crew solutions (as well as to other night work situations): repay all sleep debt and incur no sleep debt prior to night work.

An individual may estimate their sleep debt relatively easily. First, during a vacation period that does not require any sleep restriction at all and does not include nocturnal demands that preclude sleep, record the total number of hours that you sleep during each 24-hour period. This includes the major, nighttime sleep period and daytime naps. Most likely, you will experience "recovery sleep" during the first several days of the vacation. That is, you will be repaying the sleep debt that you carried into the beginning of the vacation. Eventually, you will settle into a pattern of sleeping a relatively stable number of hours per 24 hours. The average of these relatively stable amounts is your natural sleep need. Subsequently, when facing night work demands, keep track of how many hours less than this number you sleep per 24 hours. This difference is your sleep debt, and it adds up across days. The rate at which you can repay this debt varies from person to person: you can repay it with recovery sleep at a ratio of about 2:1 to 4:1. That is, if you have a sleep debt of 6 hours, you may repay it adequately with 1.5 to 3 hours of good quality, nighttime sleep.

In addition to dealing with sleep debt, the single crew involved in 24/7 operations should formulate a plan for periodic napping. This is a powerful tool for sustained operations. It is a tool that has been studied and applied extensively in the aviation community. It allowed the safe accomplishments of non-stop, around-the-world flights by the Air

[36] CA Lindbergh (1953), *The Spirit of Saint Louis*, Scribners, New York.

Force's B-1B bomber (Coronet Bat in 1995, fastest flight, 36.4 hours) and the *Voyager* (Edwards AFB, CA in 1986; no refueling; 9 days 3 min 44 sec). However, the best information available for single-crew, 24/7 operations is has been provided by Dr. Claudio Stampi, a sleep researcher at Harvard University. Himself a solo, long-distance sailor, Dr. Stampi has written, "I have been involved with numerous studies over the past 20 years that have shown that multiple napping schedules (or polyphasic sleep strategies) have allowed trans-Atlantic sailors to maintain much of their performance levels [the fastest crossing takes about 10 days]. Based on these observations and on the fact that over 85% of species in nature show typical polyphasic rest-activity patterns, we believe that polyphasic sleep is the strategy of choice for maintaining acceptable alertness levels under situations of continuous work."[37] Each individual has an optimal napping pattern. However, some generalizations may be made. One of the factors that you should consider for single-crew, 24/7 operations is whether you are an "owl" or a "lark" (early and late risers, respectively). Larks may be better at taking short naps, may prefer a regular routine and may be less efficient at night. Owls may deal better with irregular schedules, but prefer longer naps. Also, you should probably plan for and use a period of "anchor" sleep in the midnight-to-dawn period. Finally, the practical, minimum amount of sleep may be around 5 hours per 24 hours for most people.

Section G—Complex Plans

Low Weekend-Work Demands. This 4-crew, 8-plus-12-hour shift combination plan, observed in Australian military units, supports low weekend-work demands. It has a 4-week cycle. On the 20 weekdays in those four weeks, 8-h shifts are worked on in a 3nW:1nF, n = 5 system (15W:5F). One of the four crews is always off on the weekdays. On the eight weekend days in those four weeks, 12-h shifts are worked in a 2nW:2nF, n = 2 system (4W:4F). Two of the crews are off on weekends. The shift plan has a lag time of 7 days. The plan for one crew is:

SSSSSOONNNOOOODDDDD[DD]OOONN[NN]

where [DD] is two 12-h day shifts and [NN] is two 12-h night shifts. The shift plan alignment is shown in Table 21. An assessment of the combined plan is shown in Table 22. The main weakness of the plan is the seven consecutive work days.

Table 21. Shift plan alignment for the low-weekend-work-demand plan. D is an 8-h day shift, S is an 8-h swing shift, N is an 8-h night shift, [D] is a 12-h day shift, and [N] is a 12-h night shift.

Week	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	S	S	S	S	S		
2	N	N	N				
3	D	D	D	D	D	[D]	[D]
4				N	N	[N]	[N]

[37] ©Healthology, Inc. Also, see C Stampi (ed.) (1992), *Why We Nap*, Birkhäuser, Boston.

Table 22. A Principle-based assessment of the low-weekend-work-demand plan.

Plan:	8-h-plus-12-h
P1. Circadian entrainment	No
P2. Shift ≤ 8 hours	No*
P3. Few consecutive N	Yes
P3a. Few consecutive W	No
P4. O after N	Yes
P5. Max F on weekends	2 wkend per 1 mo
P6. ≥ 104 F/yr	Yes
P7. Equity	Yes
P8. Predictability	Yes
P9. Good quality time off	Yes

*On weekends, when work demand is low.

Low Night-Work Demands. A split-crew, 3-crew plan, practiced by some Canadian military units, relies upon the "skeleton crew" approach for two of three 8-h shifts per day. One whole crew works the busiest shift, the second crew splits the swing and night shifts, and the third crew is off. This plan fits into the 2nW:1nF, n = 14 system when the crew number is calculated as 2 halves per crew x 3 crews = 6 effective crews. It is a 3-crew, split-crew, 28W:14F system, using 3-day and 4-day sequences with a cycle length of (28 + 14 =) 42 days. The plan differs for the two halves of a crew, with either Days and Swings or Days and Nights for each half of the cycle. The lag time between crews (not half-crews) is 7 days. A 42-day cycle for the two halves of one crew looks like this:

½: DDDSSSSOOODDDDSSSOOOO DDDNNNNOOODDDDNNNOOOO
½: DDDNNNNOOODDDDNNNOOOO DDDSSSSOOODDDDSSSOOOO

The alignment of the split-crew plan is shown in Table 23. An assessment of the split-crew plan is shown in Table 24. Weaknesses of this plan include seven consecutive work days and four consecutive night shifts.

Table 23. Shift plan alignment for the split-crew plan.

Week	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	D	D	D	S	S	S	S
	D	D	D	N	N	N	N
2				D	D	D	D
				D	D	D	D
3	S	S	S				
	N	N	N				
4	D	D	D	N	N	N	N
	D	D	D	S	S	S	S
5				D	D	D	D
				D	D	D	D
6	N	N	N				
	S	S	S				

Table 24. A Principle-based assessment of the split-crew plan.

Plan:	**Split 3-Crew**
P1. Circadian entrainment	No
P2. Shift $\leq$ 8 hours	Yes
P3. Few consecutive N	No
P3a. Few consecutive W	No
P4. O after N	Yes
P5. Max F on weekends	2 wkend per 1.5 mo
P6. $\geq$ 104 F/yr	Yes
P7. Equity	Yes
P8. Predictability	Yes
P9. Good quality time off	Yes

Chapter 5

ASSESSMENT

This chapter covers the subject of assessing a shiftwork schedule to help you make judgments about the schedule's acceptability. Acceptability should be judged on several levels. The most comprehensive level is system effectiveness. Recall the statements from Chapter 1 that, in any human-machine system, the most unpredictable component in the system is the human and that human fatigue causes much of that variability. You should try to assess the productivity of the system with respect to shiftworker fatigue. You should also be concerned about shiftwork-related health and safety issues for the shiftworkers. Finally, you should determine how well a given schedule complies with the intentions of the scheduling Principles outlined in this Manual. In the process of gathering data to support your assessment, you will need to deal with issues about the ethical handling of the data and how to acquire and analyze data about individual shiftworkers' subjective impressions of the schedule. These issues are also covered briefly in this chapter.

Section A—Scope of Assessment

Usually, schedule assessments occur because there are questions about the adequacy of the present shiftwork schedule and thoughts about changing to a new schedule. The process to be followed is to start by conducting an assessment of the present schedule. The assessment should stand alone; it should not depend upon comparisons to a new schedule, to be designed implemented and assessed at a later date. This is because you may find that the present schedule is acceptable and no change will be made. However, the assessment should be structured such that a comparison may be made to another schedule, if needed. Thus, for objective data such as incidents or absenteeism, you should use a source of information and a measurement period that you could use again, if needed. For shiftworkers' subjective impressions, you should use questionnaires that are reliable. That is, when given repeatedly to the same people in the identical situation, you get the same answers.

A relatively comprehensive picture of a shiftwork schedule may be obtained by assessing (1) system productivity with respect to shiftworker fatigue, (2) shiftwork-related health and safety issues for the shiftworkers and (3) the compliance of the schedule with the intentions of the scheduling Principles.

Productivity. It is usually impossible to acquire direct, meaningful, useful measures of "productivity" in the workplace with regard to human fatigue. Generally, human fatigue is not identified as a factor in productivity and, thus, no directly-related measures are acquired and stored. If hourly productivity measures are available for your operation, you may be able to find patterns in them similar to the patterns shown in Chapter 1. That is, productivity may drop off after 8 hours on the job and during the pre-dawn hours. Similarly, if hourly error measures are available, you may be able to find these same patterns. These are <u>indirect</u> indicators of fatigue effects. If productivity and error

measures do not exist in your organization, you may wish to implement them so that you can get some meaningful data.

At a level of lesser detail, you should obtain data concerning turnover and personal absenteeism rates across a fixed period of several months. Occasionally, you will find that these numbers have not been examined by management and, once examined, will be found by them to be unacceptable. Usually, you will not be able to tie these numbers to the effects of the present shiftwork schedule. However, they may be useful for subsequent comparisons to the effects of a new schedule.

Health and Safety. You should obtain data concerning illnesses and illness rates, about numbers of worker compensation claims and about incidents and accidents and their rates across a fixed period of several months. Concerning the illnesses, themselves, you should look for two kinds of problems: contraindications and maladaptation.

Contraindications. Contraindications are the conditions and illnesses that suggest that an individual is not well-suited for shiftwork or night work. They include[38]:

- Conditions
  - Age over about 45, give or take 5 years
  - Extraordinary family pressures
  - Extreme "lark;" a person who always awakens by about 0500h and must always go to bed by about 2100h.
  - Long commute to the workplace
  - Need to hold a second job
  - Rigid sleep time; a person who finds it quite difficult to change their normal sleeping hours
- Illnesses
  - Asthma
  - Cardiac illness
  - Depression
  - Diabetes mellitus
  - Gastrointestinal illness
  - Insomnia
  - Seizures

Maladaptation. Maladaptation is marked by chronic and acute conditions and illnesses that suggest that an individual is not acclimating well to the physiological and sociological demands of the shiftwork schedule. They include[39]:

- Acute
  - Excessive sleepiness at work
  - Family or social problems
  - Increased accidents

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[38] AJ Scott, J LaDou (1990), *Occupational Medicine*, v. 5, no. 2, pp. 273-299. Also, A Sood (2003), *Occupational and Environmental Medicine*, v. 3, pp. 339-349.
[39] *Op. cit.*

- Increased errors
- Insomnia
- Mood disturbance

- Chronic
    - Absenteeism
    - Cardiovascular disease
    - Gastrointestinal disease
    - Separation/divorce
    - Sleep disorders

Safety. Our USAF safety investigation and analysis resources are directed primarily at Class A mishaps. However, USAF safety professionals will be the first to tell you that investigations and analyses of less-costly incidents can provide more benefits with respect to accident prevention than investigations and analyses of Class A mishaps. Class A mishaps are relatively rare events and often have causes that are complex and difficult to detect. As such, the collection of Class A mishaps experienced by the USAF across a year does not create a representative and useful sample of observations that can reveal through statistical analyses the real trends that make our operations less safe than desired.

All organizations, especially those meeting a 24/7 work demand, should track errors and minor incidents. They usually occur frequently enough in human-machine systems that the organization can build up representative samples (30 or more) of various classes of incidents quite easily. Those characteristics may then be used to help implement useful changes in procedures. The fatigue-induced incident is the relevant class of incident for shiftwork scheduling. The organization may find that it has high numbers of fatigue-induced errors and incidents associated with a specific shiftwork schedule.

How may you determine whether fatigue was a factor in any given error, incident or Class A mishap? Historically, there has been no method for determining the probable presence of a fatigue factor. Investigators of workplace and transportation accidents and incidents have seldom had the instruments or expertise required to determine whether or not human fatigue might have contributed to the mishap. Thus, a fatigue checkcard and associated protocol were designed, using the SAFTE applied model (see Attachment 2), as a screening tool to fill this need[40]. Briefly, using the checkcard, the investigator may generate a score based upon simple observations that include length of prior wakefulness, amount of prior sleep for the preceding 72 hours, time of mishap, number of night shifts in preceding 30 days, types of human errors associated with the incident, and estimated physical exertion across the work period of interest. If the score is above a criterion level shown on the card, then the investigator should contact a fatigue expert for additional help with the investigation (i.e., to confirm or negate the positive result of the checkcard screening). The checkcard is reproduced in Attachment 4. A related fatigue operational

[40] JC Miller (2005), *A Fatigue Checkcard for Mishap Investigations*; Technical Report AFRL-HE-BR-TR-2005-0071, Air Force Research Laboratory, Brooks City-Base TX, May 2005.

risk management (ORM) procedure was also designed to help reduce the risk of fatigue-induced mishaps[41].

Compliance with Principles. A tabular method for assessing the compliance of shiftwork plans with the intentions of the scheduling Principles was presented in Chapter 4. A blank table is provided here for side-by-side comparisons of various shiftwork plans (Table 25).

Table 25. Shift Plan Comparison Table.

Shiftwork Plans:	**---- Plan1 ----**	**---- Plan 2 ----**	**---- Plan 3 ----**
P1. Circadian entrainment			
P2. Shift ≤ 8 hours			
P3. Few consecutive N			
P3a. Few consecutive W			
P4. O after N			
P5. Max F on weekends			
P6. ≥ 104 F/yr			
P7. Equity			
P8. Predictability			
P9. Good quality time off			

Section B—Ethical Concerns

Research Ethics. When you set out to assess a shiftwork schedule, you may or may not be conducting "research." If you are, you must conform to specific Federal regulations concerning research ethics. If you are not, you must still be concerned about the confidentiality of the data you collect. "Research" is defined in the applicable Federal regulations for the civilian sector[42] and for the DoD[43] as being "systematic" and "generalizable." Your assessment should be systematic or it will be worthless. However, it need not be generalizable. It may be restricted in applicability to the unit being assessed.

If you wish to generalize your findings beyond the unit being assessed, then you will need to submit your research protocol to a USAF Institutional Review Board for their review and their approving official's approval. Contact the USAF Surgeon General's office for specific guidance. Ask for the administrator of the Research Oversight Committee (SGROC).

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[41] JC Miller (2005), *Operational Risk Management of Fatigue Effects*; Technical Report AFRL-HE-BR-TR-2005-0073, Air Force Research Laboratory, Brooks City-Base TX, May 2005.

[42] Code of Federal Regulations, Title 45, Part 46 (45 CFR 46), *Protection of Human Subjects*.

[43] Code of Federal Regulations, Title 32, Part 219 (32 CFR 219), *Protection of Human Subjects*.

If you wish to limit your findings to the unit being assessed, you must protect the data you collect. An individual's work, health and safety records are likely to be protected under the Privacy Act and/or the Health Insurance Portability and Accountability Act (HIPAA). Even if they are not, such records are likely to be viewed by a participant as being very confidential. In many cases, you will need to obtain approval from senior management to obtain the work, health and/or safety data that you seek. If you have a plan for protecting the data, you may show the plan to management and to potential participants to help them understand your proposed effort. Here is a USAF research method that you may use to help protect data acquired for research and for unit assessments:

- Assign a 3- or 4-digit random number to each person from or about whom you collect data.
- Keep one single, written record of the relationship between the peoples' names and their numbers on a piece of paper and protect that piece of paper in a locked cabinet or drawer.
- Identify data by participant numbers. Do not allow yourself, the participants or anyone else to associate names with data on any other piece of paper or in any computer file.
- Where a name already exists on a paper document, cut it out physically with scissors or knife, discard the name and replace it with the participant's number. Alternatively, for formal documents held by others, make a copy of the original document with the participant's name covered and keep only the copy.
- Do whatever else is necessary to keep participants' names from appearing in your research or assessment files, both on paper and in computer files.
- Even though names do not appear
- Once the data collection effort is complete and all data have been confirmed to be associated with the correct participant number, shred the written record of the relationship between the peoples' names and their numbers. Write and file a memorandum for record that documents the shredding of the written record and states that you no longer have any information that associates a participant's name with their data.

Surveys. If you wish to survey a large number of people, you may need formal USAF approval of your survey. Approval is not difficult to obtain. You must comply with AFI 36-2601, *Air Force Personnel Survey Program.* Contact the Air Force Survey Program at the Air Force Personnel Center, Randolph AFB, for additional guidance.

Section C—Questionnaires and Analyses

Questionnaires. There are several reliable questionnaires that you may wish to use as portions of a survey.

Epworth Sleepiness Scale. The Epworth Sleepiness Scale was devised at Epworth Hospital in Melbourne Australia[44]. The scale is considered to be a valid and reliable self-report measure of sleepiness. The participants use a number from 0 to 3 corresponding to the likelihood (never, slight, moderate, and high, respectively) that they would fall asleep in eight situations such as sitting and reading, watching TV, as a passenger in a car for an hour, etc. Ratings above 10 out of a possible 24 are cause for concern with respect to acceptable job performance. You should use this scale only once with a participant on a given shiftwork schedule. For example, you might use it once on the present schedule, then one more time after several months on a new schedule. The instructions and situations are:

> How likely are you to doze off or fall asleep in the following situations, in contrast to just feeling tired? This refers to all of the last week. Even if you have not done these things, estimate their effect on you.
> Use this scale, and **enter one number on each line:**
> **0.** Would *never* doze
> **1.** *Slight* chance of dozing
> **2.** *Moderate* chance of dozing
> **3.** *High* chance of dozing
>
> a. _____ Sitting and reading
> b. _____ Watching TV
> c. _____ Sitting inactive in a public place; for example, a theater or meeting
> d. _____ As a passenger in a car for an hour without a break
> e. _____ Lying down to rest in the afternoon when circumstances permit
> f. ______ Sitting and talking to someone
> g. _____ Sitting quietly after lunch without alcohol
> h. _____ In a car while stopped for a few minutes in traffic

[44] MW Johns (1991), *Sleep*, v. 14, pp. 540-545. Also, MW Johns (1992), *Sleep*, v. 15, pp. 376-381.

Survey of Shiftwork. This instrument, derived from the Standard Shiftwork Index (SSI), has been described in the research literature[45] and is available free from the website of the Working Time Society. Again, you should use this survey only once with a participant on a given shiftwork schedule. It assesses:

- Individual and situational variables (age; gender; law-enforcement shiftwork experience; work demand, or workload; the Composite Morningness Questionnaire; the Circadian Type Inventory)
- Mediator variables (overall sleep disturbances, social and domestic disruption, the Coping Questionnaire)
- Outcome variables (the General Health Questionnaire, general job satisfaction, chronic fatigue, somatic anxiety in the Cognitive-Somatic Anxiety Questionnaire, digestive symptoms, cardiovascular symptoms)

Shiftworker Satisfaction Survey. This brief survey was created for this Manual and is shown at Attachment 5. It addresses the three shiftworker satisfaction principles: equity, predictability and quality of time off. Answers are provided on bipolar, 100-point visual analog scales on two forms, comparative and absolute. The absolute form is to be used for the one-time assessment of an ongoing shiftwork schedule. The comparative form is to be used to compare a "new" shift (after several months of operation) to the preceding schedule. To help assure scale reliability, the analog scales were created with reference to the Army's Questionnaire Construction Manual[46]. Again, you should use each form of this survey only once with a participant on a given shiftwork schedule.

The USAFSAM Mental Fatigue Scale. This 7-point mental fatigue scale was created by the Crew Performance Branch of the USAF School of Aerospace Medicine, Brooks AFB, in the late 1970s, and has been used in many field and laboratory tests by researchers around the world. The participant simply circles the number of one of the seven options that best describes his or her feelings of fatigue (or lack of fatigue). A rating of 5 or higher is often cause for concern with respect to acceptable job performance. The scale may be used repeatedly within a day and across days. The seven options are:

1. Fully alert. Wide awake. Extremely peppy.
2. Very lively. Responsive, but not at peak.
3. Okay. Somewhat fresh.
4. A little tired. Less than fresh.
5. Moderately tired. Let down.
6. Extremely tired. Very difficult to concentrate.
7. Completely exhausted. Unable to function effectively. Ready to drop

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45 J Barton J *et al.* (1995), *Work and Stress*, v. 9, pp. 4-30. Also, C Smith *et al.* (2001), *Journal of Human Ergology*, v. 30, pp. 191-196. Also, C Smith *et al.* (1999), *Journal of Occupational Health Psychology*, v. 4, no. 3, pp. 207-218. Also, CS Smith *et al.* (1999), *Shiftwork International Newsletter*, June.

46 BA Babbitt, CO Nystrom (1989), *Questionnaire Construction Manual*; Research product 89-20, Fort Hood Field Unit, Systems Research Laboratory, US Army Research Institute for the Behavioral and Social Sciences, Ft Hood TX.

Karolinska Sleepiness Scale (KSS). The Karolinska Sleepiness Scale (KSS) is an alternative self-report measure of fatigue[47]. It consists of a nine-point scale, with three semantic anchors. It has been used in many field and laboratory tests by researchers around the world. The participant simply circles the number of one of the nine options that best describes his or her feelings of fatigue (or lack of fatigue). The scale may be used repeatedly within a day and across days. The options are:

1. Extremely alert
2.
3.
4.
5. Neither alert nor sleepy
6.
7.
8.
9. Extremely sleepy – fighting sleep

Stanford Sleepiness Scale. This 7-point, self-report sleepiness scale was devised by sleep researchers at Stanford University[48] and is considered to be a valid and reliable self-report measure of sleepiness. It has been used in many field and laboratory tests by researchers around the world. The participant simply circles the number of one of the seven options that best describes his or her feelings of sleepiness (or lack of sleepiness). A rating of 5 or higher is often cause for concern with respect to acceptable job performance. The scale may be used repeatedly within a day and across days. The seven options are:

1. Feeling active and vital; alert; wide awake
2. Functioning at a high level, but not at peak; able to concentrate
3. Relaxed; awake; not at full alertness; responsive
4. A little foggy; not at peak; let down
5. Fogginess; beginning to lose interest in remaining awake; slowed down
6. Sleepiness; prefer to be lying down; fighting sleep; woozy
7. Almost in reverie; sleep onset soon; lost struggle to remain awake

Analyses. When you analyze objective data about health, productivity and safety, the use of "parametric" statistics is advised. These include such descriptors as the mean and such comparison tools as the t test. However, be aware that when you analyze quantitative data about participants' subjective impressions, it is not wise to use parametric statistics. Because the data are highly unlikely to be distributed normally (the "bell" curve), the use of the mean as an average and the use of the t test for comparisons are highly likely to be misleading. The analytic approach of choice for quantified subjective data is non-parametric; that is, the calculations are not dependent upon the assumption of a normal

[47] T Akerstedt, M Gillberg (1990), *International Journal of Neuroscience*, v. 52, pp. 29-37. Also, M Gillberg *et al.* (1994), *Sleep*, v. 17, pp 236-241.
[48] E Hoddes *et al.* (1973), *Psychophysiology*, v. 10, pp. 431-436.

distribution. Some suggestions for non-parametric analyses of your quantified subjective data:

- Plot the data in histograms
- Use the median to describe the average
- Design your data acquisition so that you can use the Chi Squared test for significant differences in observed and expect distributions

These three functions are included in commercial spreadsheet applications. If your needs cannot be met by these functions, then search for a support person to conduct non-parametric correlates of the t test and tell them the following information. If you collect data from the same sample of participants under two different shiftwork schedules and you wish to compare the two "paired" samples, then a good non-parametric test is the Wilcoxon Matched-Pairs Signed-Ranks Test. If you collect data from two different samples of participants and you wish to compare the two "independent" samples, then a good non-parametric test is the Kolmogorov-Smirnov Two-Sample Test. While the names of these tests may be intimidating, the calculations are quite simple. They just require basic algebra and square root and can be accomplished easily in a spreadsheet.

Also, for the purpose of calculating a non-parametric correlation value between two paired samples of data, replace the ratings with their rank orders within each sample and use the correlation function provided in a spreadsheet. This produces the Spearman rank-order correlation coefficient.

Chapter 6

EXAMPLES

Section A—Simple 4-Crew Problem

This first example is a simple one. You are faced with the following problem for your aircraft maintenance section:

- Your manning ratio allows about 4¼ crews to cover your 24/7 operation.
- You are operating a 4-crew, 8-h, 3-shift schedule where one crew is always on days off. You must give days off—this isn't combat.
- The crews are arguing for 12-h shifts so that their quality of time off is better than with 8-h shifts. This is a reasonable request.

First, use a Work Demand Table (Table 10) to view the distribution of your personnel needs as a function of the calendar and clock. For this problem, you observe that the maximum number of people that you need equals the minimum number of people that you need. Thus, you will not be considering one of the complex solutions shown in Chapter 4. Also, for this problem, you will continue to use the usual 4-crew solution.

Second, examine the job characteristics to see if they are consistent with the use of a 12-h shift length (see Chapter 3). For this problem, you observe that the job characteristics are consistent with using a 12-h shift length. Thus, we opt to use 2 shifts per day, or a 12-h shift length.

After discussions with the shiftworkers or their ombudsmen about fixed *vs*. rotating plans, you decide to use the fastest rotation in the 2W/2F shift system. Thus, a shiftworker would see one D, one N, and two days off in each (2W + 2F =) 4-day cycle. Thus, the plan's annotation would be DNOO. This plan provides equity in the numbers of workdays and days off for all shiftworkers. It also calls for only single nights of work, a great strength that minimizes the effects of cumulative fatigue and maximizes the likelihood for circadian stability. The plan is weak with respect to the number of continuous days off: there are only 2 days off. (However, short cycle length of the plan keeps this example short.) Each worker is scheduled to work two days out of every four, giving (364 / 2 =) 182 days off per year. The average work week is 42 hours, with either 48 or 36 work hours in each calendar week.

Use a Shift Plan Table (Table 11) to show how the 4 crews will rotate and how each shift will be covered by only one crew and only once per day. Start the table like this, entering the plan from top to bottom and lagging it one day for crews B, C and D, respectively:

	Crews					
Day	**A**	**B**	**C**	**D**		**X**
1	D					
2	N	D				X
3	O	N	D			X
4	O	O	N	D		X
5	D	O	O	N		X
6	N	D	O	O		X
7	O	N	D	O		X
8	O	O	N	D		X
9		O	O	N		
10			O	O		
11				O		
12						

Finish the table like this, remembering to check (X) that each shift is covered by a crew once and only once per day:

	Crews					
Day	**A**	**B**	**C**	**D**		**X**
1	D	O	O	N		X
2	N	D	O	O		X
3	O	N	D	O		X
4	O	O	N	D		X
5	D	O	O	N		X
6	N	D	O	O		X
7	O	N	D	O		X
8	O	O	N	D		X
9	D	O	O	N		X
10	N	D	O	O		X
11	O	N	D	O		X
12	O	O	N	D		X

Note that the number of rows in the table is an exact multiple (12 days) of the cycle length (4 days). This number of rows allows a 4-day cycle that is interrupted at the bottom of the table to be continued at the top of the table. Note that the repetitious cycle (1) provides predictability of workdays and days off, and (2) requires no full-time scheduler.

Now, use the Shift Alignment Table (Table 12) to determine what kinds of weekends the shiftworkers will have. In this problem, the alignment table is (4 days/cycle x 7 days/week =) 28 days long. Enter the plan from left to right, continuing the plan from Sunday to the Monday in the next row:

Week	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	D	N	O	O	D	N	O
2	O	D	N	O	O	D	N
3	O	O	D	N	O	O	D
4	N	O	O	D	N	O	O

Thus, there are four kinds of weekends when the first day of the shift falls on a Monday: DNO, ODN, OOD, and NOO. This alignment pattern might apply to Crew A. However, when the first day of the plan falls on a Tuesday, the weekend types are ODN, OOD, NOO, and DNO, as shown here:

Week	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	O	D	N	O	O	D	N
2	O	O	D	N	O	O	D
3	N	O	O	D	N	O	O
4	D	N	O	O	D	N	O

This alignment pattern might apply to Crew B. Note that this alignment produces the same types of weekends as above for Crew A, just in a different order. All four crews will have the same types of weekends. Equity across crews and shiftworkers is achieved by this plan in terms of the quality of time off. However, there are only one "good" Saturday and one "good" Sunday in each 4-week cycle (days off on which the shiftworker is not recovering from night work).

Because humans are not designed to work at night, all shiftwork plans have their strengths and weaknesses. Finally, you must now interact with your shiftworkers to determine which schedule is best for your people and your operation. This interaction must take into account the DNOO plan, shift overlap, shift differentials (money or time, or both) and shift start times.

Section B--3-Crew Deployment

This second example is an analysis applied to a real operational problem. The report from the field was that people were working 13+ hours per day and that some personnel had worked "weeks without time off." The tasks being conducted required a high level of vigilance, focused attention, and communication in a non-user-friendly environment. In response, management proposed to deploy 2 crews of 4 people each and one extra worker for 120 to 179 days, to work 12-hr shifts with 6 days on and 1 day off. It was not clear how the days off would be arranged; presumably by rotating the workers through the extra-worker slot. Unfortunately, if equity were to be achieved across shiftworkers, this approach allowed only 1 day off in 9, not 1 day off in 6.

The assessment of this proposal was that it was a "stupid" way to operate, making the human operators "stupid" as defined in Chapter 1 and for the reasons outlined for 2-crew solutions in Chapter 4. Instead of this approach, management was advised to consider the Close 6 schedule described in Attachment 3, assuming that (1) the deployed shiftworkers would be living and working in the same, small geographic area, and (2) work demand was equal across all days of the week and all hours of the day. This plan would have required the deployment of 12 people (3 crews of 4) instead of 9 people. Across each 72-h period, they would work 6 h on, 6 h off, 6 h on; 12 h off; again 6 h on, 6 h off, 6 h on; and then have 24 h off.

A Shift Plan Table broken down into quarters of the day for this plan shows the need for a 24-hour crew lag; the first work period of each 72-h period is shown in bold for each crew:

		Crew					
Day	**Hour**	**A**	**B**	**C**			**X**
1	**12:00**	**W**	O	O			X
1	**18:00**	O	O	W			X
2	**0:00**	W	O	O			X
2	**6:00**	O	O	W			X
2	**12:00**	O	**W**	O			X
2	**18:00**	W	O	O			X
3	**0:00**	O	W	O			X
3	**6:00**	W	O	O			X
3	**12:00**	O	O	**W**			X
3	**18:00**	O	W	O			X
4	**0:00**	O	O	W			X
4	**6:00**	O	W	O			X
4	**12:00**	**W**	O	O			X
4	**18:00**	O	O	W			X
5	**0:00**	W	O	O			X
5	**6:00**	O	O	W			X
5	**12:00**	O	**W**	O			X
5	**18:00**	W	O	O			X
6	**0:00**	O	W	O			X
6	**6:00**	W	O	O			X
6	**12:00**	O	O	**W**			X
6	**18:00**	O	W	O			X
7	**0:00**	O	O	W			X
7	**6:00**	O	W	O			X

The last main thing to be considered for this deployment plan was the need for and the effect of shift overlap.

Section C—Complex Schedule

The last example is, again, a real shiftwork schedule analysis and recommendation for an operational squadron with a 24/7 work demand. It is a complicated example involving a split crew solution, but describes a real operational problem.

The squadron was dealing with quality of life issues after more than 1000 days of 24/7 operations at a surge pace. They had more than 1000 days of use-or-use leave on the books, and Squadron *esprit de corps* was low. One source of great concern on the part of the Squadron Commander and Operations Officer was their shiftwork schedule.

The squadron had adopted a nominal 12-hour shift length with a 3-hour shift length differential: the day shift was 15 hours long (0700h-2200h) and the night shift was 9 hours long (2200h-0700h). These two shifts were subdivided into blocks for scheduling flexibility. The day shift was divided into three 5-hour blocks and further divided into 2.5-hour blocks. A crew worked in two 2.5-hour blocks during one day of work, while a Mission Commander worked a 5-hour shift. The night shift was divided into three 3-hour blocks. A crew worked in two 3-hour blocks during one work night.

The squadron had also adopted a daytime shift system of approximately 5W, 1F, 5W, 3F, and a nighttime shift system of approximately 6W, 1F, 6W, 1F, 6W, 4F. A group of workers would work day shifts most of the time and then be scheduled for 18 non-consecutive night shifts across 24 days about once every 3 months (nominally, 9/24ths of the time). Because the 14-day day-work system and the 24-day night-work system were not simple and were not compatible with each other, all scheduling was *ad hoc*. That is, schedulers spent large amounts of time assigning individuals to time slots and then making changes on the basis of individual requests and individual needs for deployment, TDY, training, and additional duties. A partial example is shown in Table 26. The schedule was quite irregular and largely unpredictable and, thus, there appeared to be a potential for scheduling inequities. Good quality of time off was limited. These problems are known to affect morale and retention.

Table 26. Partial sample of existing schedule; one line per crewmember; D = day shift, N = night shift.

Workers	Days													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A	D	D		D			D					D	D	D
B					D	D	D	D	D		D			
C	D	D	D	D		D			D	D	D	D		
D		D	D	D	D	D		D	D	D	D	D		
E	N	N												D
F		D	D	D						D	D	D		D
G	N	N				D	D	D		D			D	D
H		N	N	N	N		N	N	N	N	N	N		N
I		N	N		N	N	N	N	N	N		N	N	N
J						D		D	D	D	D			
K	D	D	D	D	D					D	D	D	D	
L			D	D			D				D			
M	D				D	D	D	D	D		D	D	D	D
N										D	D	D		

The strengths of the existing shiftwork schedule at the squadron were the internal flexibility allowed by the blocks within shifts and the selection of the nominal 12-hour shift length. It is important to keep in mind that this was non-continuous work; that is, no one worked all 15 daytime hours or all 9 nighttime hours. However, the squadron's existing selection of the nominal 12-hour shift length helped us to apply regular, predictable, equitable shift scheduling concepts to the scheduling needs of the squadron.

Considering the shiftwork Principles, we identified four keys for meeting the scheduling needs of the squadron:

- Keep the flexibility for non-continuous work allowed by the blocks within a 12-hour shift
- Keep their 0700h shift start time
- Use a 4-team shift system of the structure 1nW:1nF
- Use an administrative structure in which an Element has the ability to operate all potentially active workstations and the control center.

The following recommendations were based upon these four keys.

Administrative Structure. Organize the Squadron into four Flights of two Elements each to meet the shiftwork demand. Within each Flight, one Element should emphasize morning work ("larks") and the other should emphasize afternoon work ("owls"). An Element was required to have the ability to operate all potentially active workstations and the operations center.

Shift Plan. We considered these plans in the 1nW:1nF system, among others:

- n = 1, DNRO
- n = 2, DDNNROOO and DDNRNROO

- n = 3, DDDNRNRNROOO

Balancing the scheduling Principles and the realities of operations at the squadron, we recommended the use of the DDNNROOO plan with three caveats. These caveats were aimed at balancing the prevention of chronic fatigue with the need to accomplish additional duties. First, shiftworker rest during the transition from days (D) to nights (N) should be managed actively by the squadron. The shiftworkers should be taught that, during this 24-hour period (0700h to 0700h), they are to engage only in a prioritized list of activities:

1. Pay back any sleep debt incurred
2. Take care of home and family needs
3. Complete take-home administrative work from the squadron

The squadron should not allow shiftworkers to participate in wing or base activities on this day and should discourage shiftworkers from working voluntarily at the squadron early during the day.

Second, shiftworker rest following the second night of work should be managed actively by the squadron. This is a daytime period (0700h-1900h) during which as much recovery sleep as possible should be obtained by the shiftworker. The squadron should not allow shiftworkers to participate in squadron, wing or base activities on this day and should discourage shiftworkers from working voluntarily at the squadron during the day.

Third, shiftworker time during the free day (0700h to 0700h) prior to the first day shift should be managed actively by the squadron. Shiftworkers may be allowed during this "stand-by" period (especially 0700h to 1700h) to engage in squadron, wing and base activities. Thus the shift plan becomes:

DDNNROOS

where S is a stand-by day. Thus, some additional duties could be accomplished on the Stand-by Day and, to a limited degree, during the transition from days to nights. They may also be accomplished during W periods when not at a workstation.

Blocks. Each 12-hour shift (D and N) should be subdivided into four 3-hour blocks (Figure 7). The first two blocks of a shift should be the nominal responsibility of the commander of the "lark" Element within a Flight. The last two blocks of a shift should be the nominal responsibility of the commander of the "owl" Element within a Flight.

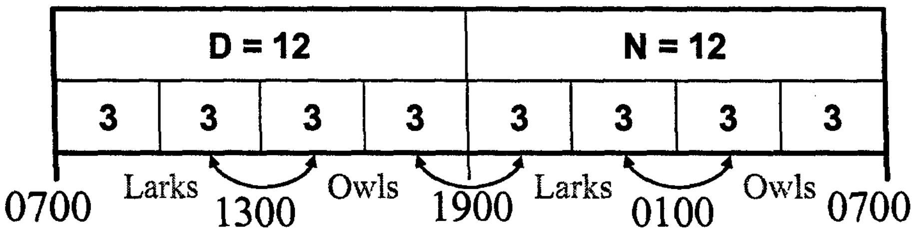

Figure 7. Proposed shift structure containing a 12-hour day shift (D), a 12-hour night shift (N) and 3-hour blocks within shifts. The first two blocks of a shift are the nominal responsibility of a "lark" Element and the last two blocks of a shift are the nominal responsibility of an "owl" Element. Shiftworkers may flex across the "lark-owl" and D-N boundaries.

Each crew should be at a workstation during two blocks in one D or one N shift, for a total of 6 hours per shift. A shiftworker may be available for up to another 3 hours of additional duties in a D or N shift. Shiftworkers in the "lark" Element of a Flight should be at workstations during the first blocks of the D and N shifts, beginning at 0700h and 1900h, respectively. Crews in the "owl" Element of a Flight should be at workstations during the last blocks of the D and N shifts, beginning at 1600h and 0400h, respectively.

By arrangement between Element commanders within a Flight, shiftworkers may flex across the "lark-owl" boundaries within the D and N shifts at 1300h and 0100h, respectively. Also by arrangement between Flight commanders, shiftworkers may flex across the D-N boundary at 0700h and 1900h.

Shift Alignment. The 8-day cycle interacts with the 7-day week to come out even at 56 days (Table 27). The 56-day rotation occurs exactly 6.5 times in each 364-day shiftwork year. Thus, each Flight experiences exactly 6.5 rotations per year. There are 8 types of weekends (Table 27), and all shiftworkers experience exactly the same numbers of each.

Table 27. 56-day shift rotation for one Flight, where D is a day shift, N is a night shift, R is a recovery day and S is a stand-by day. The eight types of weekends are shaded.

Week	M	Tu	W	Th	F	Sa	Su
1	D	D	N	N	R	-	-
2	S	D	D	N	N	R	-
3	-	S	D	D	N	N	R
4	-	-	S	D	D	N	N
5	R	-	-	S	D	D	N
6	N	R	-	-	S	D	D
7	N	N	R	-	-	S	D
8	D	N	N	R	-	-	S

In any given 24-hour period, one Flight covers the 12-hour day shift with two Elements, one covers the 12-hour night shift with two Elements, and the other two Flights are on R, S or free days (Table 28). Note that shiftworkers are only available on stand-by every

other day. If needed for special activities, it is arithmetically possible to swap an S day with the preceding free day and sustain schedule equity. However, this is a poor way to manage the shiftworkers: the contiguity of the free days is valuable with respect to morale and retention.

Table 28. Two cycles (16 days) of shift rotations across four Flights, where D is a day shift, N is a night shift, R is a recovery day and S is a stand-by day.

	Flight			
Day	A	B	C	D
1	D	-	R	N
2	D	S	-	N
3	N	D	-	R
4	N	D	S	-
5	R	N	D	-
6	-	N	D	S
7	-	R	N	D
8	S	-	N	D
9	D	-	R	N
10	D	S	-	N
11	N	D	-	R
12	N	D	S	-
13	R	N	D	-
14	-	N	D	S
15	-	R	N	D
16	S	-	N	D

Employment Ratio. In addition to the number of shiftworkers within an Element needed to operate all workstations and the operations center, manpower is needed to cover deployment, TDY, annual leave, and illness. The percentages associated with these requirements were determined to be 10%, 5%, 8% and 1%, respectively. Thus, each Element should be manned at 124% to accomplish its mission.

Advantages. The adoption of the specific shiftwork recommendations, above, should provide schedule equity and predictability, and better-quality time off for the shiftworkers. In turn, one may expect fewer on-the-job errors, increased morale and less management attention spent on individual shiftworkers' schedule changes. In fact, "scheduling" *per se* will not be needed: the rotation continues automatically into the future. Schedule changes and flexing should be managed by Element and Flight commanders.

Other Recommendations

Increase involvement by the local SGP Human Performance Training Team (HPTT):

- Brief fatigue and sleep hygiene to new shiftworkers.
- Work closely with leadership and SG to monitor shiftworker fatigue continuously through surveys and interviews and to provide fatigue briefings, educational materials and fitness recommendations to shiftworkers.

Reduce social pressures:

- Establish spouse awareness day to get spouse buy-in of mission, make them feel part of the team. Have HPTT brief spouses on fatigue and sleep hygiene, focusing on why proper sleep environment is important.

Operations center:

- Set up a nap room in the utility room so that fatigued shiftworkers can take power naps. Establish unit policy authorizing and encouraging naps.
- Increase ambient lighting during night shifts to suppress melatonin production.
- Improve workstation ergonomics to reduce physical fatigue. Computer keyboards are set too high at workstations. Raise seats and provide footrest. Move keyboard closer to operator. Adjust seats so they are inclined 10 to 20 degrees back.
- Provide simple exercise equipment. Mild exercise can increase alertness for up to 15 to 30 minutes. Examples: small weights, stationary bicycle, bungee cord (good for limited spaces), sit-up mat, pull-up bar, etc.

Pharmacological interventions:

- Pursue the use of Ambien®, Sonata® and Restoril® (no go pills) and Modafinil® (go pill) as needed though SGP.
- Use caffeine pills and drinks only as needed. Post caffeine guidelines (how much, when to take) in break room, operations center and workstations. Teach shiftworkers to check nutritional supplements for caffeine and guarana extract.

Chapter 7

ADDITIONAL READING

This Manual defines Principles and Components of shiftwork scheduling that minimize fatigue effects in the workplace, and provides scheduling approaches, assessment tools and examples for regular, cyclic schedules in 24/7 operations. Additional information may be acquired by visiting the World Wide Web sites of the National Sleep Foundation and the Working Time Society. Also, the following publications may be consulted:

- *Biological Rhythms: Implications for the Worker*, U.S. Congress Office of Technology Assessment report OTA-BA-463, 1991. Available from the U.S. Government Printing Office.
- *Making Shiftwork Tolerable*, by Timothy H. Monk and Simon Folkard, CRC Press, 1992. (ISBN 0850668220)
- *Shiftwork Safety and Performance*, by Peggy Westfall-Lake and Glenn N. McBride, Lewis Publishers, 1998. (ISBN 1566702577)
- *The 24-Hour Business*, by Richard M. Coleman, American Management Association, New York NY, 1995. (ISBN 0814402402)
- *The Practical Guide to Managing 24-Hour Operations*, by the Editors of *Shiftwork Alert,* Circadian Technologies, Inc., Cambridge MA, 1999. (ISBN 0964889315)

ATTACHMENT 1

GLOSSARY

Acrophase. The radial alignment of the circadian peak relative to midnight.

Acrophase time. The time of day or night at which of the circadian peak occurs.

Chronohygiene. Healthful time management with respect to the wake-sleep and work-rest cycles.

Circadian. From the Latin, *circa* (about) and *dia* (day): a cycle length of about one day. That is, one high point (peak) and one low point (trough, or nadir) per 24 hours.

Cycle length. The sum of all workdays and days off in one full cycle of the plan; also, the sum of all work and free days in the shift system.

Employment ratio. Makes allowances in schedules for holidays, sick leave, vacation, and training.

Equal assignments. All crews work an equal number of day (D), swing (S), and night (N) shifts.

FAST™. The computer software implementation of the SAFTE applied model.

Fatigue, mental. Feelings of sleepiness, low vigilance and/or low alertness.

Fatigue, performance. Inability to accomplish the task at hand due to preceding mental or physical overexertion and/or extended wakefulness.

Fatigue, physical. Muscle weakness due to overexertion.

Rotation, backward. A shift rotation that is characterized by rotating to a shift that starts earlier in the day than the current shift. For example, rotating from a 07:00-15:00 day shift to a 00:00-07:00 night shift.

Rotation, forward. A shift rotation that is characterized by rotating to a shift that starts later in the day than the current shift. For example, rotating from a 07:00-15:00 day shift to a 15:00-23:00 swing shift.

Lag time. The number of days of delay between the time a second crew starts its shift cycle and the time the first crew started its shift cycle.

Malaise. General definition: Physical discomfort (as mild sickness or depression). Health definition: A vague feeling of bodily discomfort.

Rota. A shift plan

SAFTE. An applied model, or simulation, of fatigue effects on cognitive performance effectiveness.

Shift alignment. The relationship of a shift plan with the calendar week.

Shift cycle. The length of time required to work completely through the shift plan, working all shifts. Usually, the sum of all work and free days in the shift system.

Shift differential. Hourly pay rates or shift lengths that differ between, for example, day and night shifts.

Shift overlap. The time spent before and after a shift to transition control of the system from the crew ending its shift to the crew starting its shift. Overlap is not used in calculations and comparisons of shiftwork plans. However, overlap must be used for calculations of total numbers of hours worked and pay, after the shiftwork plan has been selected.

Shift plan (or shift *rota*). The sequence of the work (W) and free (F) days in a shift system.

Shift rotation. Changing from one shift to another, such as from the day shift to the swing shift, within one shift cycle and without an intervening free day.

Shift schedule. Includes the shift system, shift plan, shift alignment, shift cycle, lag time, differentials, etc.

Shift system. The numbers of days allotted to work and rest. Expressed as the ratio XnW/YnF where X and Y are integers that describe the general form of the shift system, m and n are multipliers (also integers), W represents work days, and F represents free days.

Shiftworker. A worker who works non-standard shifts that include evenings, nights and/or weekends.

Sleep hygiene. Healthful time management with respect to sleep quality.

Work compression. In the zero-sum nature of 24/7 operations, work compression is used to allow the expansion of continuous time off. In a zero-sum system, any gain within the system must be offset by an equal loss within the system. In practice, work compression means that once you arrive at work you stay there more hours. In return, you have more continuous hours off within a specified number of days or weeks or months. A common example of work compression is working four 10-hour days per week and having a 3-day weekend, instead of working five 8-hour days and having a 2-day weekend.

Work demand. The average numbers of hours worked by a worker per year, per week, and/or per day. May be calculated without overlap for shift schedule comparison purposes, and with overlap for pay purposes.

ATTACHMENT 2

SAFTE and *FAST*™

The Sleep, Activity, Fatigue and Task Effectiveness (SAFTE) applied model integrates quantitative information about (1) circadian rhythms in metabolic rate, (2) cognitive performance recovery rates associated with sleep, and cognitive performance decay rates associated with wakefulness, and (3) cognitive performance effects associated with sleep inertia, to produce a 3-process applied model of human cognitive effectiveness.[49]

The Fatigue Avoidance Scheduling Tool (*FAST*™) is based upon the SAFTE applied model. *FAST*™ was developed initially as an Air Force product under the Small Business Innovation Research program to deal specifically with Air Force scheduling issues. It is a Windows® program that estimates the average effects of various work-rest schedules on human cognitive performance by entering work and sleep data in any of several formats. Graphic plots from *FAST*™ are used later in this Manual.

Schematic of SAFTE Model

Sleep, Activity, Fatigue and Task Effectiveness Model

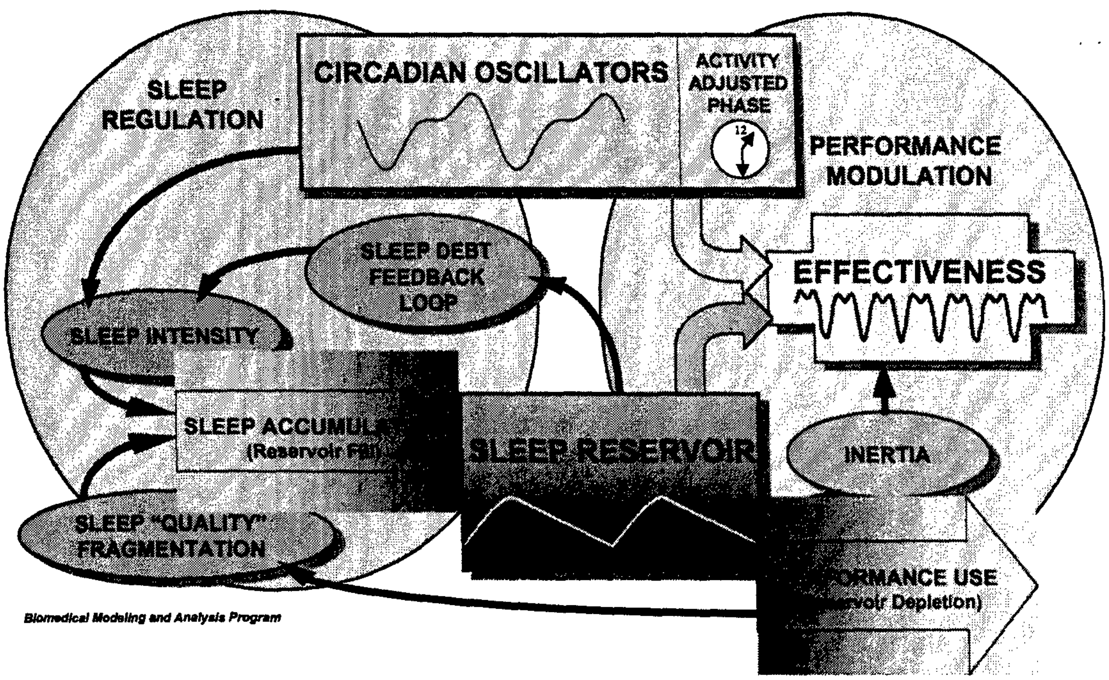

Figure 8. Schematic of the SAFTE model.

[49] S.R. Hursh *et al.* (2004), *Aviation, Space and Environmental Medicine* 75(3 Section II Supplement), pp. A44-A53.

The general architecture of the SAFTE applied model is shown in Figure 8. A circadian process influences both cognitive effectiveness and sleep regulation. Sleep regulation is dependent upon hours of sleep, hours of wakefulness, current sleep debt, the circadian process and sleep fragmentation (awakenings during a sleep period). Cognitive effectiveness is dependent upon the current balance of the sleep regulation process, the circadian process, and sleep inertia.

The SAFTE applied model has a number of essential features that distinguish it from other attempts to model sleep and fatigue (Table 1). Together, these features of the applied model allow it to make very accurate predictions of performance under a variety of work schedules and levels of sleep deprivation. The model:

- Is "homeostatic." That is, gradual decreases in sleep debt decrease predicted sleep intensity, and progressive increases in sleep debt to increase predicted sleep intensity. Thus, it predicts a normal decline in sleep intensity during a sleep period and predicts a normal equilibrium of performance under less than optimal schedules of sleep.
- Delays sleep accumulation at the start of each sleep period ("sleep latency"). Thus, it predicts the detrimental effects of sleep fragmentation and multiple interruptions in sleep.
- Incorporates a multi-oscillator circadian process (a 24-hour cycle plus a 12-h cycle). Thus, it predicts the normal, asymmetrical cycle of cognitive performance around the clock.
- Is additive for the circadian process and the sleep-wake cycle. Thus, it predicts the normal mid-afternoon dip in performance, as well as the more predominant, though normal, nadir in performance that occurs in the early morning.
- Modulates the intensity of sleep according to the time of day. Thus, it predicts normal circadian variations in sleep quality and normal limits on performance under work-rest schedules that require daytime sleep.
- Includes a factor to account for the initial lag in performance upon awakening. Thus, it predicts sleep inertia that is proportional to sleep debt.
- Incorporates adjustment to new time zones or shift schedules. Thus, it predicts temporary "jet lag" effects and adjustment to shiftwork (shift lag).

Software Implementation of the Model. The Fatigue Avoidance Scheduling Tool (*FAST*™) is based upon the SAFTE applied model. *FAST*™ was developed initially as an Air Force product under the Small Business Innovation Research program to deal specifically with Air Force scheduling issues. It is a Windows® program that estimates the average effects of various work-rest schedules on human cognitive performance by entering work and sleep data in any of several formats. A graphic plot from *FAST*™ is shown in Figure 9. This original *FAST*™ research software was designed for use by scientists in studies of human sleep and circadian rhythms. Because of extensive exposure to Air Force safety officers, flight surgeons, physiological training officers, and operational units, the research software became a sought-after fatigue-management tool. Unfortunately, the scientist-oriented user interface of the research software puzzled most of the potential users in these operational communities. A project was beginning in fiscal

year 2006 within the Air Force Research Laboratory to design easier-to-use fatigue management tools for mission planning, performance assessment, and status reporting. The tools were to use the SAFTE model and many of the design concepts from the original *FAST*™ software, and were to focus specifically on several operational areas, including shiftwork scheduling.

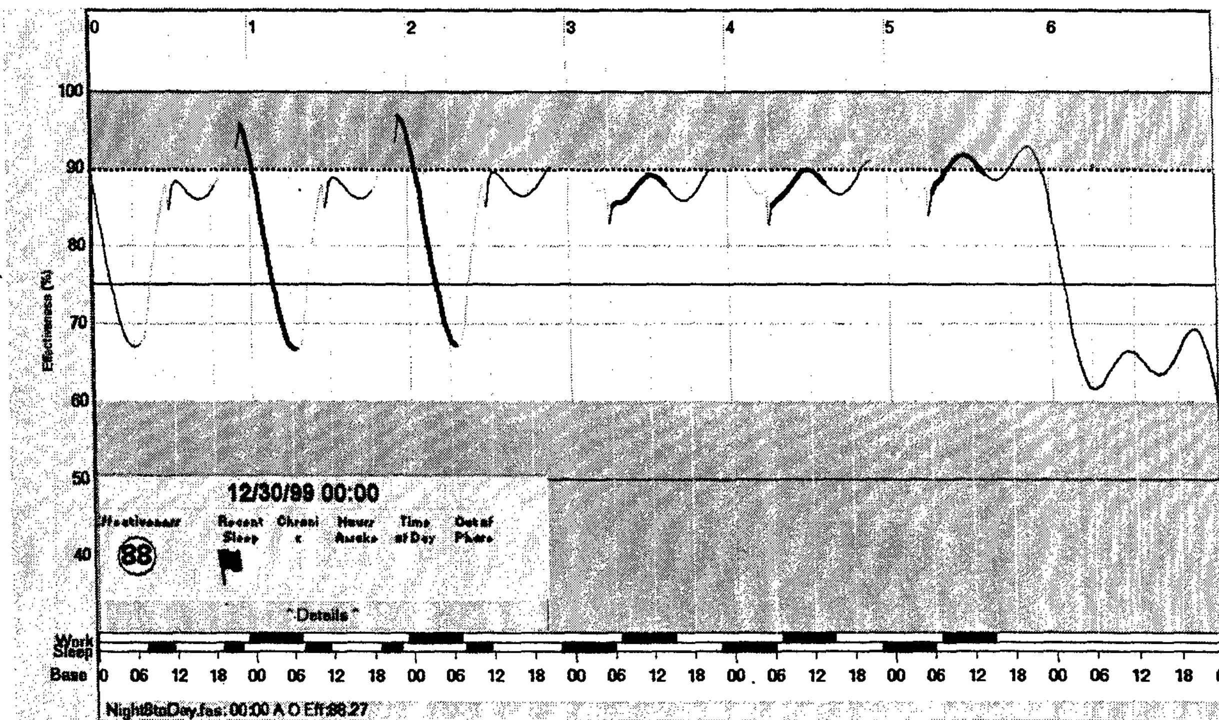

Figure 9. Screen shot of *FAST*™.

ATTACHMENT 3

SHIFT LENGTHS OF 4, 6 AND 24 HOURS

These shift lengths are used by the maritime community (4 and 6 hours) and the urban firefighting community (24 hours). They are presented here as alternatives to be considered when you face a very unusual work demand.

4-Hour Shifts. The 4-hour shift (watch) length is used in almost all military and commercial maritime operations. We may call it the fixed (*i.e.*, non-rotating), classic maritime watch. The genesis of the traditional 3-crew (or 3-watch section), 4-h plan in marine operations is obscure. However, it is likely that it came into use at least 700 years ago because it meets two criteria: (1) 4 h is a factor of both the 24-h day and an 8-h work day, and (2) 4 h is viewed as a length of time during which one can stand upright without excessive fatigue.

Even though each crew must work 56 hours per week, three crews on board a ship may be just the right number. With two crews on 12 h of work per day, too many fatigue-induced errors might occur. The use of four crews to reduce fatigue effects would present other problems. With four crews working 6 h per day, or working 8 h per day and taking one day in four off, crew members would probably become bored and inefficient (and sometimes mutinous). Also, the ship would need to carry 1.3 times as many people, and supplies for them, as it does for three crews.

Standing a watch often entails *standing* during the entire watch. Certainly, there is historical precedent for seamen literally standing a watch. Whether or not 4 h is a reasonable amount of time to stand depends in part upon muscle tone in the legs and the cardiovascular capabilities of an individual, but it is a physically demanding effort, particularly in high sea states. Whatever the reason, standing for 4 h and then taking an 8-h break from constant standing is obviously more palatable than standing for 8 h without a break.

The main problems with the traditional 4-and-8 maritime watch plan are reduced total sleep time and fragmented sleep. With only 8 hours off between watches, the watchstander is never able to get the eight hours of continuous, uninterrupted sleep found by clinicians and researchers to be the average sleep need. Thus, many maritime watchstanders operate at a continual, unacceptably-low level of cognitive performance effectiveness (usually about 80% to 90%) while the vessel is underway.

An alternative to the standard, fixed 4-and-8 watchstanding schedule was proposed to the submarine fleet by Dr Nathaniel Kleitman, later to become the father of sleep research[50]. Work compression was used within each watch section to allow non-watch periods of 10

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[50] RA Utterback, GD Ludwig (1949), *A Comparative Study of Schedules for Standing Watches aboard Submarines Based on Body Temperature Cycles*; Report no. 1, Project 004 003, Naval Medical Research Institute, Bethesda MD. (AD-667-707), Figure 2.

hours and more per section while maintaining 8 h watch per section per day. We may call this the fixed, Close 4 watch. The Section watch schedules were:

- Section I: 0800-1000h, 1200-1600h and 2000-2200h; 10 h off watch, 2200-0800h
- Section II: 0300-0500h, 1600-2000h and 2200-0000h; 11 h off watch, 0500-1600h
- Section III: 0000-0300h, 0500-0800h and 1000-1200h; 12 h off watch, 12-0000h

This plan will be useful when a team will live and work 24/7 in a very limited geographical area.

6-Hour Shifts. Navy submarines began operating on an 18-h work-rest cycle with 6-hour watches in the 1960s. All watchstanders stood watch for six hours and were then off for 12 hours. Then they repeated the cycle. This practice, coupled with the absence of strong daylight-darkness time cues, caused the circadian rhythms of the watchstanders to desynchronize from the 24-h daily cycle. This reportedly induced malaise among watchstanders. The inability of the watchstanders' circadian rhythms to entrain to an 18-h work-rest cycle was not surprising: the limits of entrainment were shown in recent years to be about a 23- to 25-h cycle.

On the 18-h work-rest cycle, watchstanders slept about seven hours per 24 hours. Since most people operate best on more than seven hours of sleep per 24 hours, many submariners operated with a chronic sleep deficit. Anecdotal reports indicated that the prevalence of both jet-lag-like malaise and sleep deficit were high among submarine watchstanders who worked the 18-h work-rest cycle.

An alternative, compressed plan with 6-hour watches was designed. We call it the rotating, Close 6 watch. It provided work demands equivalent to those of the classic maritime and submarine watch schedules; that is, 24 hours of watchstanding per 72 hours. The work-rest sequence started at noon and included 6 hours on, 6 off, 6 on; 12 hours off; 6 hours on, 6 off, 6 on; 24 hours off. The plan implemented as much as possible the scheduling Principles. Specifically, the plan was designed to:

- Minimize the exposure to night work
- Start each 72-h work sequence at noon, when crew members are relatively well rested
- Locate the most error-prone hours, pre-dawn and mid-afternoon, near the start of the sequence, when crew members are relatively well rested
- End each 72-h work sequence at noon, allowing adequate recovery sleep to be acquired at night
- Maximize the balance between the number of people available and time spent off from watchstanding; and
- Take advantage of the fact that the human circadian rhythm is slightly longer than 24 hours by rotating forward on the clock.

A laboratory study indicated that the Close 6 plan provided more total sleep than the classic maritime and the submarine watch schedules[51]. Unfortunately, a subsequent field trial showed that this alternative plan was unworkable while underway due to difficulties in the scheduling of a multitude of training sessions and drills, a problem that was unexpected even by the Submarine Fleet's Senior Chiefs. However, the Close 6 plan will be useful when a team will live and work 24/7 in a very limited geographical area.

24-Hour Shifts. There is widespread use of a 24-h shift length in urban fire houses in Canada and the United States. Thus, obviously, many professionals view the 24-h shift length as being acceptable. However, to help determine the acceptability of 24-hour shifts, you must consider how many crews are used to cover the 24/7 work demand.

One can use either 12-h or 24-h shifts with either 3 or 4 crews, but 12-h shifts with 3 crews provides too little time off: shiftworkers would probably never have more than 2 consecutive days off, the first of which would follow a night shift. Employers probably observed that it was cheaper many years ago to employ 3 crews than 4. However, with 3 crews, they also probably found that it was essential to use work compression (*i.e.*, the 24-h shift instead of the 12-h shift) to allow acceptable amounts of continuous time off. They probably learned this because of personnel attrition caused by shiftworker dissatisfaction with unacceptably-short periods of time-off. This may be the historical context within which 24-hour shifts came to be associated with urban firefighting. It was an acceptable and efficient method for employing only 3 crews.

Subsequently, because of rules and expectations generated by such actions as the US Fair Labor Standards Act, many firefighting agencies moved to 4-crew solutions to the 24/7 work demand to get the average work-week length down from 56 to 42 hours. Subsequently, as with workers in nearly all shiftwork systems, some firefighters have pressed for work compression (24-h shifts in this case) with 4 crews to gain longer continuous periods of time off. Since 24-h shift lengths have been used widely in urban firefighting, they are viewed by firefighters as an acceptable approach to work compression.

Given that we understand to some degree the context of using 24-h shifts in urban firefighting, the question is whether 24-h shift lengths are truly acceptable in a work domain or are "stupid," as defined in Chapter 1. The work domain is a system within which the shiftworker is but one component, along with equipment, environment, specific tasks, etc. Is the shiftworker on a 24-h shift safe and effective at work? Or does he or she impair system performance due to cumulative fatigue acquired from a poor shiftwork schedule?

A 24-h shift length may acceptable if there is a very strong sleep-on-the-job mentality among management and the shiftworkers. This mentality should promote and support the

[51] 62. JC Miller *et al.* (2003), *Effects of Three Watchstanding Schedules on Submariner Physiology, Performance and Mood*; Technical Report 1226, Naval Submarine Medical Research Laboratory, Groton, CT, March.

idea that "Any sleep is good." High-quality daytime naps during the 24-h shift must be encouraged and supported by management for the purpose of eliminating any existing sleep debt.

Second, nocturnal work must be only intermittent and good-quality nocturnal sleep on the job should be planned for and supported. There must be a strong, positive sleep-recency effect during nocturnal work. This recency effect will give the 24-h shiftworker an advantage over other night workers who, because of job design, must work continually through the night and have no chance to sleep at night.

Finally, work compression does lead to longer continuous periods of time off. Long continuous periods of time off are probably a good idea for emergency workers who are under a relatively high threat of bodily injury or death on the job and who often undergo relatively high levels of physical and environmental stress (heavy fire protection gear, climbing, handling high pressure hoses, heat, etc.).

Given that 24 hours may be an acceptable shift length, with the sleep caveats, above, and that long continuous time-off periods may be desirable, what might be an optimal shift plan? With 4 crews, a given crew must work ¼ of the time. Thus, the crew might work 1 day (24-h shift) on and have 3 days off; or 2 days on and 6 days off; or 1 day on, 1 day off, 1 day on and 5 days off. With 5 or 6 days off, many shiftworkers will become involved in second jobs and/or extra schooling. As long as these activities do not impair their "fitness for duty" (or "readiness to perform") upon return to work, they should not be of concern to management. With 3 crews, a given crew and the individuals on that crew must work 1/3 of the time. Thus, the crew might work 1 day (24-h shift) on and have 2 days off.

ATTACHMENT 4

FATIGUE CHECKCARD

(next two pages)

AFRL FATIGUE CHECKCARD FOR MISHAP INVESTIGATIONS

A. Length of Prior Wakefulness (LPW)	**Rating**
LPW <= 16 hrs	1
16 <= LPW < 19 hrs	3
LPW > 19 hrs	5
B. Amount of Prior Sleep for the Preceding 72 h (APS)	
APS >= 21 hrs	1
18 <= APS < 21 hrs	3
APS < 18 hrs	5
C. Time of Mishap (TOD)	
0600 < TOD <= 2200h	1
2200 < TOD <= 0100h	3
0100 < TOD <= 0600h	5
D. Number of Night Shifts in Preceding 30 Days (NNS)	
NNS >= 15	1
8 <= NNS <= 14	3
NNS < 8	5
E. Time Zone Change and Days in Zone	
[Any time change (hours) / Days in zone] < 3	1
Time change of 6 to 12 hours and days in zone > 1	3
Time change of 6 to 12 hours and days in zone <= 1	5
F. Types of Human Errors Associated with Mishap	
Injured; impeded by poor interface design	1
Distraction	2
Poor planning; bad decision	3
Slow reaction time	4
Fell asleep; dozed off	5
G. Estimated Exertion Across the Work Period of Interest	
No exertion at all or extremely light	1
Very light or light	2
Somewhat hard or hard (heavy)	3
Very hard	4
Extremely hard or maximal exertion	5
SUM	

AFRL/HEPF
October 2004

Fatigue Checkcard Notes:

- Use your judgment to provide interpolated scores of 2 and 4, as needed, for Factors A through E and to adjust other scores. Document your reasoning for interpolations and adjustments.
- **Factor A**, length of prior wakefulness, refers to the continuous period of wakefulness leading up to the mishap. Thus, if the mishap occurred three hours after the person awoke from a night of sleep, the amount would be three hours and the score would be 1. If the mishap occurred 20 hours after the last nocturnal sleep period, then the amount would be 20 hours and the score would be 5. You have some leeway in determining the last "good quality" sleep period from which to start counting. Generally, nocturnal sleep is better than daytime naps for recovery from fatigue. However, some people are good nappers who experience substantial recovery in naps. In this case, a daytime nap may be used as the last good sleep period.
- **Factor B**, amount of prior sleep for the preceding 72 hours, refers to the total amount of "good quality" sleep acquired in that period. Again, you have some leeway in determining the occurrence of "good quality" sleep. Generally, nocturnal sleep is better than daytime sleep.
- **Factor C**, time of day/night of the mishap, should be self-explanatory.
- For **Factor D**, number of preceding night shifts in preceding 30 days, a higher score means that the worker has had fewer nights to acclimate to night work. If during days off between night shifts the worker reverted to a day waking and night sleeping pattern, then increase the score by 1 or more. For the well-acclimated night worker who makes a change to day work, the same scores may be used as those used for the acclimation to night work. Change the description of the factor to "Number of preceding day shifts in 30 days" and document the immediately preceding acclimation to night work.
- Similarly, for **Factor E**, time zone change (in hours), a higher score means that the worker has had fewer days to acclimate to the new time zone. The calculation works for changes up to 12 hours (half-way around the globe). For changes greater than 12 hours, subtract the change from 24 hours and use the remainder in the calculation. For example, a 14-hour change becomes a (24 – 14 =) 10 hour change.
- For immediate <u>night</u> work in a distant time zone after a rapid change of 9 to 12 hours east or west by a day worker, score only the fatigue effects of the time zone change. For immediate <u>day</u> work in a distant time zone after a rapid change of 9 to 12 hours east or west by a day worker, assume that the effects of the time zone change and shift change are additive. The converse is somewhat true, also, for a night worker that moves rapidly across time zones. However, note that the night worker is highly likely to be fatigued before the time zone change and increase the score accordingly.
- For Factors D and E, it is unlikely that one individual will be involved in both shiftwork and time zone transitions at the same time. Thus it is likely that, if Factor D is scored then Factor E will not be scored and vice versa.
- For **Factor F**, types of human errors associated with mishap, use the highest score among all types of human errors thought by investigators to contribute to the mishap.
- **Factor G**, estimated exertion across the work period of interest, accounts for physical fatigue as it may have existed at the time of the mishap.
- Collect and document all data relevant to the Checkcard factors to the extent possible. The data sources will be best estimates by mishap personnel, by colleagues and family of mishap personnel and by the investigators.

Fatigue Checkcard scoring: If any single factor's score is a 5, or if the sum of the seven ratings is 21 or higher, or if the average score (sum / 7) is greater than 3, then fatigue may have been a factor in the mishap.
Fatigue Checkcard use: If fatigue might have been a factor, then contact a fatigue expert for additional help in the investigation. The expert should confirm or negate the tentative, Checkcard-based finding.

AFRL/HEPF
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ATTACHMENT 5

Shiftwork Satisfaction Survey
AFRL/HEPF
Brooks City-Base, Texas
Form A—Comparative

Date __________ Participant number ______________________________

When we ask you to work nights and weekends, we must try to make sure that your shiftwork schedule gives you the best quality of life that is consistent with the organization's needs. Please answer the next three questions using the following rating scale, and then make comments and suggestions in question 4 about both shiftwork schedules.

Using this scale of *Worst of all* (-50) to *Best of all* (+50), rate your present schedule compared to your previous schedule by writing a number from –50 through +50.

Worst of all	Moderately Worse	**Borderline**	Moderately Better	**Best of all**
-50	-23	0	+23	+50

1. Compared to your previous schedule, does your present schedule provide better or worse "**quality of time off**?" Quality of time off means different things to different people. Three common issues are how awake and alert you feel on your days off, the length of each time-off period, and the number of weekend days that you are off.
   Number (-50 to +50) _____

2. Compared to your previous schedule, does your present schedule provide better or worse "**equity**?" Equity means that, across several months, you and all of your co-workers work the same number of nights and weekends and have the same quality of time off.
   Number (-50 to +50) _____

3. Compared to your previous schedule, does your present schedule provide better or worse "**predictability**?" Predictability means that you can predict your work days and days off far enough ahead that you can plan your life adequately.
   Number (-50 to +50) _____

4. Other positive and negative comments about both schedules, and suggestions:

Shiftwork Satisfaction Questionnaire
AFRL/HEPF
Brooks City-Base, Texas
Form B—Present Schedule

Date ___________ Participant number ______________________________

When we ask you to work nights and weekends, we must try to make sure that your shiftwork schedule gives you the best quality of life that is consistent with the organization's needs. Please answer the next three questions using the following rating scale, and then make comments and suggestions in question 4 about your present shiftwork schedule.

Using this scale of *Totally inadequate* (-50) to *Totally adequate* (+50), rate your present schedule by writing a number from –50 through +50.

Totally Inadequate	Pretty Inadequate	**Borderline**	Pretty Adequate	**Totally Adequate**
-50	-24	**0**	+25	**+50**

1. Does your present schedule provide good "**quality of time off**?" Quality of time off means different things to different people. Three common issues are how awake and alert you feel on your days off, the length of each time-off period, and the number of weekend days that you are off.

   Number (-50 to +50) _____

2. Does your present schedule provide good "**equity**?" Equity means that, across several months, you and all of your co-workers work the same number of nights and weekends and have the same quality of time off.

   Number (-50 to +50) _____

3. Does your present schedule provide good "**predictability**?" Predictability means that you can predict your work days and days off far enough ahead that you can plan your life adequately.

   Number (-50 to +50) _____

4. Other positive and negative comments about your present schedule, and suggestions: